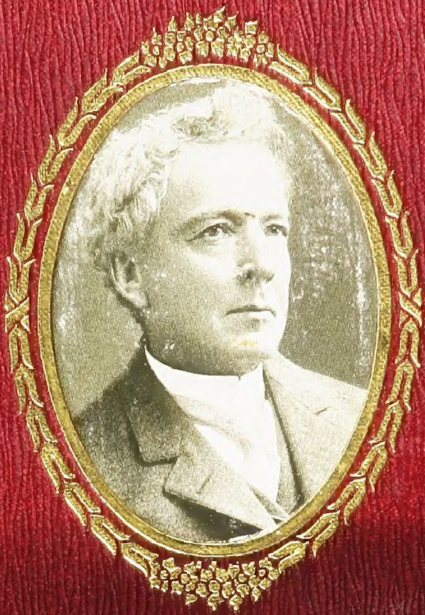

The Burbank Rose

This picture reproduces a direct color photograph from an oil painting. It represents the celebrated Burbank rose with the utmost fidelity. This is the rose that secured a gold medal at the St. Louis International Exposition in 1904, as the best bedding rose. It furnishes a striking illustration of the fact that Mr. Burbank's efforts at plant development are as successful in the case of the commonly cultivated flowers as with the rare ones.

LUTHER BURBANK

HIS METHODS AND DISCOVERIES AND THEIR PRACTICAL APPLICATION

PREPARED FROM
HIS ORIGINAL FIELD NOTES
COVERING MORE THAN 100,000 EXPERIMENTS
MADE DURING FORTY YEARS DEVOTED
TO PLANT IMPROVEMENT

WITH THE ASSISTANCE OF

The Luther Burbank Society
AND ITS
ENTIRE MEMBERSHIP

UNDER THE EDITORIAL DIRECTION OF

John Whitson and Robert John
AND
Henry Smith Williams, M. D., LL. D.

VOLUME IX

ILLUSTRATED WITH
105 DIRECT COLOR PHOTOGRAPH PRINTS PRODUCED BY A
NEW PROCESS DEVISED AND PERFECTED FOR
USE IN THESE VOLUMES

NEW YORK AND LONDON
LUTHER BURBANK PRESS
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Volume IX—By Chapters

Foreword to Volume IX

Of all the hours Mr. Burbank has put in among his plants, the best, to him, are those spent with his flowers.

Here, in this volume, we see not only his flower masterpieces and a clear portrayal of the methods used in their production—but a close view portrait of Luther Burbank, the man.

We see him in the very act of increasing the size, changing the scent, remodeling the shape, bringing forth a new color—we see him transforming weeds into glorious flowers—always doing what others have said was impossible.

Coupled with the definite method explanation, there is ever present an entrancing interest, abounding in helpful suggestions, the crystallized essence of a rich experience, to every lover of flowers.

THE EDITORS.

Fragrant Sweet Peas

Mr. Burbank has a very keen sense of smell, and he is always on the lookout for flowers that show exceptional qualities of fragrance. Many sweet peas are quite odorless, but here are some in which Mr. Burbank has developed an exquisite fragrance. Careful observation and persistent selective breeding have been the watchwords here as with so many other experiments.

WHAT TO WORK FOR IN FLOWERS

AND HOW TO PROCEED

ONE of my plant developments that usually interests the visitor as much as almost any other has to do not with the flower or fruit of a plant but with the leaf.

The plant in question is a species of "wild geranium" known as *Heuchera micrantha,* a native of the western coast, and the anomaly of leaf that attracts attention is the curiously erected, crinkled, and corrugated condition that makes the foliage of this plant quite unlike that of any other member of the tribe that anyone has seen. Indeed the new variety is so changed from its ancestral type that it is considered entitled to recognition with the varietal name *cristata* added to its technical title. Were it found growing in the woods instead of in a garden, it would be pronounced a new species altogether.

The story of this anomalous geranium will serve as well as another to introduce our studies of the development of new varieties of flowers, even though the particular development under consideration has to do with the leaf of the plant, and not with its blossoms. The principle of development is the same in its application to each part of the plant, and we shall see plenty of illustrations of work with the flowers themselves before we are through.

The wild geranium, of which the plant with the strange leaf is a modified representative, is a plant that normally has leaves some of which are rather decorative because of their very slightly scalloped margins, but which in general are quite plain. Some of the leaves are flecked with brownish spots, but the surface is quite smooth, as much resembling an apple or geranium leaf as any other. Even botanists have never taken special notice of any variation in the form of the leaf.

There is, however, a marked tendency to variation in different specimens, especially in the brown spots on the leaves, and the crimson shadings in the fall.

A New Leaf By Selection

Several years ago, in examining some of these plants growing wild on a rocky ledge over Mt. St. Helena, I observed one that had leaves slightly crinkled at the edges. This slight, almost insig-

A Metamorphosed Leaf

In the center above, an ordinary leaf of the Heuchera, or "wild geranium"; at right and left below, different types of crested leaves of the same plant developed by Mr. Burbank through selective breeding. The story of this modification of a leaf, as told in the text, has peculiar interest. Doubtless many other plants have similar possibilities of development, and many an amateur should be stimulated to emulate Mr. Burbank's example; for the results of this particular experiment are at once novel and striking.

nificant, variation suggested the possibility that farther variation in the same direction might take place if the plants were educated in the right way. So I transferred the plant with crinkled leaves to my home grounds, and in due time gathered its exceedingly diminutive black seeds.

When the little plants that grew from these seeds next season were carefully examined, I observed that some of them had leaves slightly more crenated or crinkled than the others. So even before the plants made much growth I was able to weed out about half of them, as showing no evidence of progress in the desired direction.

When the plants were still larger, but before any flowers appeared, about half of the remainder were pulled up; and later in the season still others were discarded that had shown the crinkled condition at an earlier period but did not tend to carry it well as they advanced in age.

Of the many thousands with which I had started in the spring, only a handful remained toward seed time. And at last a single one among these was chosen as presenting leaves that from the point of view of the experiment were best.

This single plant was allowed to mature its seed.

The plants that grew from this seed, representing now the second filial generation from the original wild plant, were treated in precisely the same way. But it should be recorded that there was great improvement in this second generation. Now three-quarters of the plants showed leaves that were markedly crinkled. Each plant produces thousands of seeds, and progress was relatively rapid, as great numbers could be produced from which to select.

By process of elimination, the one best plant was again selected and its seed preserved.

In the next generation, practically all of the plants showed the curiously modified form of leaf.

In the fourth generation, as before, very large numbers of plants were raised that there might be wide opportunity for selection. Now all the plants presented the crinkled leaves, but there were of course individual specimens that excelled, and these were chosen to the exclusion of the others.

Their progeny bore uniformly crinkled leaves of the most pronounced type, and they constitute the new species *Heuchara cristata* as it grows to-day.

The remarkable crinkled and convoluted leaves are so interesting that they are sometimes preserved by electroplating, to be used as ornaments. They give the plant a very curious and individual appearance, and present a striking illustration of what may be done, by mere inbreeding

Variation in Color As Well As Leaf Form

These are different examples of Mr. Burbank's curiously crested "wild geranium"—a plant that has been so modified as to merit botanical classification as a fixed variety. It will be seen that there is marked variation in color as well as form. By selective breeding, the color variations might be fixed just as the corrugated condition of the leaf has been. The modification shown has been effected by selective breeding alone, without hybridization.

and systematic selection, to develop and accentuate a plant characteristic.

No one who casually observed the old parent form of the plant and the new modified form growing side by side would be likely to suspect that the two belong to the same species. Yet an examination of the flowers would show that these are identical, for in making the successive selections I paid attention to the leaf exclusively, and did not seek in any way to modify other portions of the plant's structure.

To the person who has not had experience in plant development, probably the most remarkable feature of the entire matter is the comparatively short time required, and the few generations involved, in producing what is a remarkable transformation—the most conspicuous transformation in a leaf that has ever been produced. The nearest approach to this structure is seen in the leaf of the Rex Begonia called *Erdody*. It may seem further remarkable that a transformation of such significance could be effected in a few generations by selective breeding; without the aid of special experiments in hybridizing.

But this case is presented here at the beginning of our special studies of flower development, largely to emphasize the possibility of modifying even so fixed a structure as the leaf of a plant merely by selection of individual specimens that vary in a given direction for a few generations.

I would emphasize, however, the necessity of operating with a large number of specimens if one is to obtain the best results in the shortest practicable time. The account of the experiment just given makes it clear that by having large numbers to choose from, I was enabled to discard numberless specimens that would have answered the purpose *fairly* well in favor of the single specimen that showed the desired quality modified *pre-eminently.*

The Question of Hybridizing

This case, as was said, illustrates the possibility of producing striking results in plant modification by mere selection without hybridization. No effort was made to induce the plant to vary more rapidly, first because there seemed no necessity for stimulating it to further variation, and secondly because no plant was at hand which presented such a character as the one I wished to develop.

Yet it should not be overlooked that there was an element of pollenizing involved, even though the pollenizing was not done by the plant experimenter. This is almost axiomatic because of course the plant would have produced no seeds unless its pistils had been pollenized.

Yellow Tritoma, or "Red Hot Poker"

This interesting flower is now undergoing observation in Mr. Burbank's garden. There are marked variations in color in the flowers, as will be shown in a subsequent picture, and these appeal to Mr. Burbank as offering opportunities for modification through selective breeding. Hence the attention that is now being shown this rather spectacular plant.

All that I had done, to be sure, was to transplant the original geranium to a bed where it was isolated from any other plants of its species. But such isolation in itself served to provide that the pistils of the plant should be fertilized with pollen from its own flowers.

In other words, by isolating this *heuchera* with crinkled leaves it had been determined that the pollen and ovules from the selected plant should combine to produce the seed germs for the next generation. And in so doing I made sure that both hereditary strains—that brought by pollen and that brought by ovule—should have the same hereditary factors, because they were borne on the same plant.

This, then, was a case of inbreeding, or "intensification" which has been mentioned previously. It was as far removed as possible from the hybridizing experiments we have witnessed in which species of widely different type, say the strawberry and the raspberry, were interbred. In such a case as that, the pollen and the ovule bring groups of hereditary factors that are widely divergent. And even in the usual cases of cross-fertilization within a species, where pollen of one plant is brought to the pistil of the flower of a neighboring plant, there is a certain opportunity for the mingling of diverse hereditary factors, inasmuch as no two plants are precisely alike.

But in the case of our *heuchera*, the flowers were self-fertilized or at most the pollen from one flower was transferred by an insect to the pistil of a neighboring flower on the same stalk, and thus it was arranged that both hereditary strains should be as nearly identical as is possible.

In the essential matter of the form of leaf, the hereditary factors brought by the pollen grains called for a leaf with crinkled edges; and the hereditary factors carried by the ovules had the same specifications. So there was the best possible chance that the offspring would reproduce or accentuate the parent character.

And yet the results show that there must have been a certain amount of diversity among the various pollen grains and ovules even of the single plant, inasmuch as the plants that grew from its seed were diversified in character.

About half of them, it will be recalled, did not present the crinkled leaf to any extent and were at once eliminated.

And the other half showed the character in varying degree.

Indeed, no two of them were precisely identical, so we are justified in the conclusion that no two pairs of pollen grains and ovules brought precisely

Tritomas Showing Color Variations

These tritomas with red tops and yellow bottoms illustrate one of the interesting color modifications of this flower. Where a plant shows such tendency to vary, it offers plastic material in the hands of the developer. Contrast the tritomas in this picture with the preceding and the succeeding ones.

the same combination of hereditary factors together.

When we consider the matter in this light, it will be evident that all pollenizing experiments are in a sense hybridizing experiments in one degree or another, inasmuch as they all of necessity bring together pollen grains and ovules that vary somewhat, even if only in very minor degree, in their hereditary factors.

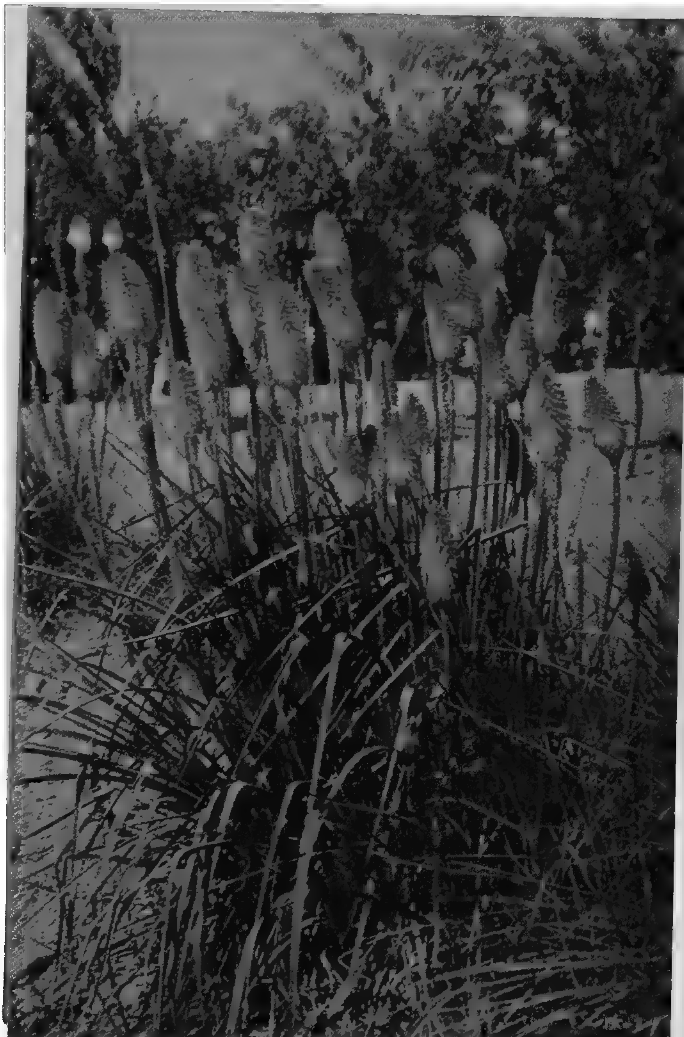
But it remains true—and indeed is too obviously true to require comment—that the case of the pollen grains united with pistils on flowers of the same plant (the case, that is to say, of the *heuchera* under consideration) is that in which there is the least possible degree of variation between the two sets of elementary factors that are combined.

Therefore this process of so-called inbreeding introduces the least possible disturbing elements, and gives the largest probability of the reproduction of any given trait of the mother plant—which in this case is the father plant as well.

The practical results have been already illustrated in the production of this new race of *heuchera* with leaves crinkled and corrugated in unique fashion so that they differ fundamentally from the characteristic leaves of any other species or variety.

The lesson to be drawn, then, from this experiment is that when we wish to modify a plant as to some particular feature of its anatomy, we shall proceed to best advantage if we (1) select an individual that shows the most marked departure from the normal in the desired direction of any that can be found; (2) isolate this plant so that its flowers shall be self-fertilized, or else hand pollenize them; and then (3) follow out a similar course of selection of the best individual and self-fertilization of its flowers through successive generations until the maximum amount of variation in the desired direction that is attainable has been produced. It sometimes hastens the process to combine two or more of the best plants by crossing rather than to depend on a single one.

We shall see in other connections, as indeed we have previously seen in our studies of many plants, that it is frequently desirable to stimulate variation by hybridizing plants that are divergent, even plants of different species. But when an individual plant presenting an approach to the desired variation or modification has been found among the hybrid progeny, the successive steps of inbreeding and selection, through which the character is accentuated and fixed, will be carried out precisely as in the case of the little *heuchera* just cited.



All-Red Tritomas

With a bunch of these red tritomas and a bunch of the variegated ones shown in the preceding picture in the garden, there is opportunity for an interesting crossbreeding experiment, to observe color variation. We shall see that numberless flowers offer opportunities for similar studies in color variation; and that few other lines of plant development afford more interesting or more striking results than those that have to do with the modification of the color of flowers.

Indeed, had we been able to take up the story of our little *heuchera* a generation or two earlier, we should have found, in all probability, that such a crossbreeding experiment as has just been suggested had been performed for us by Nature. It is highly probable that the original specimen with the tendency to crinkled leaves that was found in the woods was the product of a cross between plants, perhaps of the same species, that were individually widely variant from one another. The plant grew on a cliff where very dry, very moist and very unusual conditions of the sun, the shade, moisture and soil prevailed, thus having current in its heredity a tendency to vary more or less, since heredity is only the visible effect of near and far environments.

Whatever the individual peculiarities of the parents of this particular plant, the individual that I found had leaves that were somewhat highly accentuated in a certain direction, being thus proved to be the possessor of a somewhat unusual combination of hereditary factors for leaf formation.

In a word, then, whereas the experiment with the little *heuchera* may be described as consisting exclusively (so far as the plant developer was concerned) of a series of selections, it really involved also the principle of the inducement of variation by crossbreeding and the fixing of characters by inbreeding.

And these fundamental principles of plant development must be involved, in one degree or another, in all successful experiments in the development and fixing of new types of plant form or leaf or flower or fruit.

Let us now witness the application of the same principles to the flower of the plant with reference to the different characteristics of size and color and odor and modified petal or stamen or pistil that may be involved.

Producing a Desired Fragrance in the Flower

Probably no other characteristic of the flower is more highly prized than its odor.

The rose and the carnation owe their popularity as much to their fragrance as to their color and form, yet there are numbers of very beautiful and popular flowers that are quite without attractive fragrance. There is no line of experimental work with the flowers that should be more attractive to the amateur than the development of fragrant varieties of some of these odorless flowers.

And fortunately it is an undertaking that may be expected to produce very satisfactory results—as immediate, as striking, and as valuable results as from any other plant experiment. In any group of odorless flowers, you may have the good fortune to detect, if you search carefully enough, one that differs from its fellows in having at least a suggestion of fragrance. And if you will work in the right way with this individual, you will probably be able to produce a race of perfumed flowers—supplying you, therefore, with a flower different from anything in the garden of your neighbor, and adding the finishing touch to a blossom which, however attractive otherwise, could not be considered perfect so long as it lacked this finishing quality.

In an earlier volume we have heard the story of the fragrant Calla.

The reader will recall that this anomalous variety, known now as the Fragrance, was developed by simple selection, along the lines just illustrated in the case of the little *heuchera,* with the difference merely that the characteristic borne constantly in mind was fragrance of the Calla blossom instead of a peculiar conformation of leaf.

By "line-breeding" and careful selection, I was enabled in a few generations to isolate a calla that has delicious fragrance while retaining all the other qualities of the flower unchanged.

The seedlings of this selected calla are not invariably fragrant. By careful inbreeding the fragrant calla could without doubt be made to breed true to the quality of fragrance. In the particular

A Bed of Daffodills

These daffodils are growing beside Mr. Burbank's house. They were placed there for ornamental purposes, in all probability; but it is fairly certain that Mr. Burbank will note variations among them, and will select out various ones for further breeding experiments. It would be quite impossible for Mr. Burbank to have a bed of flowers of any kind thus growing beside his house without seeing opportunities for experiments that he could not resist.

case of the calla, this is of no special importance, as the plant is propagated by division.

But in plants that are propagated solely by seed, the fixing of the quality of fragrance would be essential.

Fortunately it presents no special difficulties once a fragrant variant has been found.

In a later chapter we shall learn of other experiments in producing fragrant flowers, and details will be given of the story of my fragrant verbena which was introduced under the name of Mayflower. The amateur who wishes to experiment along these lines may begin with almost any odorless flower in the garden. It is only necessary to search for delicate traces of fragrance, and to learn to recognize nice shades of distinction among odors. Anyone can readily detect the difference in fragrance in several varieties of the violet, roses, or carnations, for example; and a still more highly cultivated odor-sense enables one to notice differences in the fragrance of apple, peach, or almost any other blossoms from different trees or plants.

So it is not necessary to confine one's experiments to flowers that lack fragrance altogether. Interesting results may be obtained by selecting among fragrant flowers those that have the most pleasing perfume, and developing those races that are especially notable for their fragrance.

The failure to give attention to the matter of fragrance sometimes leads to the cultivation of a special variety of fragrant blossom that has altogether lost its perfume. An illustration of this came to my attention not long ago when visiting the seed farm of the best known seedsman in America. He showed me his new varieties of sweet-peas with great pride; and when I called his attention to the fact that a number of them were totally lacking in fragrance of any kind, he was not a little surprised.

He was breeding sweet-peas for immense size and had succeeded, through selection, in producing very striking varieties.

But he had taken it for granted that all sweet-peas are fragrant, and had before failed to observe that these particular ones had no perfume whatever.

Yet this seedsman is an expert who has been for nearly forty years in the business of growing flowers. Like perhaps most others, he had taken it for granted that all varieties of fragrant flowers are fragrant. Series of experiments in crossbreeding would be necessary to reintroduce the perfume to these varieties that have lost this finishing quality.

This case is mentioned to illustrate the fact that a given quality may be dropped out of a strain of

A Bed of Scotch Buttercups

These are commonplace flowers, hardy and thrifty, such as grow in countless gardens. But Mr. Burbank has selected the best seeds from the few superior plants in similar beds for several seasons, and although no spectacular result has been obtained, there is a general betterment that is suggestive of future possibilities—perhaps not to be realized until hybridizing experiments supplement the experiments in pure selection.

flowers while another quality is being bred in. Also to emphasize the point that it is usually well to consider more than a single quality in any breeding experiment.

At least it is desirable to see that the qualities already present are not lost in the process of gaining new ones.

Producing New Colors

I am disposed to think that all shades of all colors that can be produced by blending of the primary colors are within the possible attainment of any flowering plant.

The obvious fact that certain species, and in some cases whole genera, produce only red flowers, others only blue ones or yellow, does not by any means prove that the plants in question have not the capacity to produce flowers of quite different color.

We have seen that the colors of wild flowers have been given them by insects. We have noted that the bright colors—reds, orange, blues—have been assumed by flowers that flourish in the daytime and seek association with the bees; and that the flowers that consort with night flying insects, such as moths, are almost universally decked in white or pale yellow—hues that make them far more conspicuous in the twilight than the most brilliant scarlet flower would be.

Most wild flowers of a given species are of a single color, or of a definite arrangement or combination of colors. Bees and other insects have learned to distinguish this characteristic color or combination of colors, and to go with certainty from one flower to another of the same species, thus unconsciously serving the flower well by cross-pollenizing its blossoms.

I have often thought how confusing it must be to the bees on coming to our gardens to find flowers that perhaps are familiar to perfume and form, now arrayed in a dress of unfamiliar hues. But bees, like flowers, can adapt themselves to their environment. They soon adapt themselves to the new colors and combinations of colors that man has given the flowers, and they go about their task with undiminished celerity and certainty.

Recognition of the fact that wild flowers have been given their colors by the insects through the slow process of natural selection (in which flowers that lack the color were not visited by the bees and hence produced no offspring; whereas the flowers that did produce the color were fertilized, and perpetuated their kind, and reproduced their qualities in abundant progeny) gives us the clue to the way in which we may go about the development of a new color or color-combination in a flower.

Suppose, for example, we desire to change the

Forget-Me-Nots

There chanced to be an unoccupied space along this fence, and a glance at it sent Mr. Burbank to his seed room, with the ultimate result here depicted. Like all Mr. Burbank's seeds, these are carefully selected ones, as their thrifty growth and prolific bearing amply testify. It is well worth while, Mr. Burbank believes, to practice selective breeding even with the most commonplace flowers in your garden.

flower from white to yellow. How shall we go about it?

First of all, we must produce thousands of seedlings from our white flower. Let them blossom, and then search among them with the keenest eye to detect a trace of yellow color—which is found more or less in all white flowers—in the flowers of any single plant.

You are almost certain, if your scrutiny is sufficiently keen, to detect some plant that varies an infinitesimal shade from its fellows, showing at least a trace of yellow; for a really pure white is extremely rare in Nature.

Select the seed of this plant; sow it next season; and repeat the process of searching.

You will almost certainly be rewarded, if not in the first season, then in the second or third or fourth, by finding flowers that show very much more marked traces of yellow than the original flower. And even if the variation is not very striking at first, you will probably find that it tends to be accentuated after a few generations, especially in certain individuals. Each year you will discover flowers that are yellower than any of the preceding season; and presently you will have a blossom that is as yellow as you could desire, and a new race of plants that will breed true from seed. Placed side by side with the white flowers that were their ancestors, your new race will present a striking contrast.

The fact that you have thus been instrumental in virtually creating a new type of flower can scarcely fail to give you real satisfaction and pleasure.

The fact that you have a flower such as perhaps no one else in the world possesses, and that this has been produced by intelligent and persistent effort, must be a source of quite justifiable self-gratulation.

In subsequent studies we shall see that there are methods of stimulating the production of new colors and color combinations through hybridization. But in this introductory chapter I am dealing chiefly with the simpler cases, and suggesting experiments that the amateur may undertake at the outset.

The more complex cases will command his attention in due course.

Meantime it should be stimulative to reflect that, by mere selection, demanding no knowledge of botany, no expert knowledge of horticulture, but only the possession of reasonably acute vision and the exhibition of patience and persistence, it is possible to develop in the most commonplace flower-garden blossoms whose color is at once unique and of enhanced beauty.

Nor need attention be restricted to mere matters of fragrance and color.

I have already suggested that it is usually well to consider more than a single quality. Cases like that of the *heuchera* leaf, in which for a special purpose a single quality alone is considered, are exceptional. As a rule, you may advantageously bear in mind, at the same time that you are developing a new fragrance, the question also of color of flower, and size, and form.

At all events, so soon as your experiment has reached the stage at which you have a number of fragrant flowers from which to select, all of which have about the same excellence of perfume, you will, as a matter of course, choose among these the one that combines with fragrance the most desired qualities of color and form and size of blossom.

Doubling the Petals and Increasing Size

As to the matter of size, it is obvious that not much need be said. A glance shows which plant bears the largest flowers. And it may confidently be expected that the offspring of this plant will tend to produce flowers of exceptional size, and that some among these will exceed the parent plant in this regard.

Precisely the same method of selecting, generation after generation, with size of flower always in view, will lead to the production of a race of

Coreopsis or Golden Wave

A selected Burbank variety, differing only in minor details from a good many other varieties. The coreopsis is one of the flowers that Mr. Burbank commends to the attention of the amateur, as being easy of cultivation and responsive of temperament.

plants that tend to produce uniformly, under the right conditions of nourishment and care, flowers of a far larger size than those of the ancestral form.

The matter of producing double flowers from a single variety—that is to say, flowers having two or more rows of petals instead of a single row—may present greater difficulties. Not, indeed, that any new principle is involved, but merely that a longer series of experiments may be required to produce the coveted double flower. The start must be made here just as in the other cases, by searching among the hundreds or thousands of plants for one that bears flowers having even a single extra petal.

Seed of this plant being sown, it is likely that among the offspring there will be some that produce not merely one extra petal, but possibly two or three.

The Three Requisites

Now you are on the road to success. Thenceforward it is only a matter of time, skill, and patience—the three essential requisites of plant development — combined with the dealing with large numbers of individuals.

Exceptionally there may suddenly appear a seedling producing flowers that are fully double. In such a case, if the truth could be known, it would propably appear that some of the ancestors of the seedling had produced—perhaps generations back—a double or partially double flower. Breeding from a double rose or carnation, almost all the seedlings revert to a single or semi-double form.

But in any event, once you have singled out a strain of flower that has the tendency to produce extra petals, you will probably find this tendency accentuated, manifesting what I have elsewhere referred to as the momentum of variation, and giving you results that are more and more encouraging each season.

Asking Too Much

Should you attempt to produce a double flower coincidently with the attempt to improve the scent and color and size of the same flower, you may presently discover that you are asking rather too much.

The flowers that improve in odor and color and size may not be the ones that show the increased tendency to doubling of petals.

In such a case, you may segregate the two groups, and carry forward the two lines of experiment coincidently in neighboring plots; and when you have attained a fair measure of success in giving one race of flowers perfume and color and size, and the other race a double or triple or

Bulb-Planting Time at Santa Rosa

Note the straight sharp-edged furrow, made with the aid of a plank. All bulbs are planted in this way at Santa Rosa, as Mr. Burbank could not bear to see his garden pets put out in a haphazard or unsymmetrical manner. Part of Mr. Burbank's success must be ascribed to the meticulous care with which he supervises all details of the work of plant culture.

quadruple row of petals, you may readily make a crossbreeding experiment through which you may combine all the desired qualities in a single hybrid offspring.

Even if the first-generation seedling of such a cross does not give you just the combination you are seeking, the second generation offspring or a subsequent one are almost sure to reveal some plants that meet your expectations.

So your simple experiments that began by mere selection will probably lead you to experiments in crossbreeding.

The Two Basic Elements

Thus by natural stages you will have learned how to handle the essential tools of the plant developer. You will have learned that the two forces of heredity and environment are everywhere operative, and must everywhere be your sole dependence. But you will have learned also that your wishes become an important part of the environment, when you determine which flowers shall be permitted to reproduce their kind; and that you also take a hand at determining the line of action of hereditary tendencies when you cross-pollinate the flowers, and decide which strains of heredity shall be blended.

Let me in concluding this preliminary chapter name two or three common flowers with which the amateur may advantageously begin his work in selective breeding.

The rose and the carnation naturally suggest themselves, but they have been so much worked on that they do not leave so much opportunity for wide improvement as some less popular flowers, though offering grand opportunities for immediate but less unique results.

The tulip is inviting, but calls for a good deal of patience.

Perhaps the four o'clock would serve the purpose as well as any other common flower. Also the hyacinth, the scylla, and the gladiolus are peculiarly good flowers on which to work. There are many beautiful varieties of all of these but new sorts could readily be produced. Moreover, they are grown from bulbs, so any new varieties may easily be perpetuated—a consideration that is by no means without significance to the amateur who wishes to obtain striking results with the least expenditure of time.

Details as to numerous other flowers, including both very common ones and those that are less usual, and varying from the simplest to the most complex, will come to our attention as we now take up in succession the records of my own work during the past four years in the development of new races of flowers.

Working With a Universal Flower—The Rose

How the Burbank and Other Roses Were Produced

THE most popular of any roses I have so far introduced is undoubtedly the one known as the Burbank.

The popularity of this rose is, I trust, well deserved. But I should not be disposed to admit that its merits are greater than those of many of my newer roses which have not yet made their appearance in public. The popularity of the Burbank is partly to be explained by the fact that it has been a good while before the public.

There is a time element in the introduction of a new flower, just as in the introduction of a new fruit. In fact, no new plant development could be expected to make its way except very gradually at first, although it gains momentum rapidly after a time. In this regard, the introduction of a flower is analogous to the development of the flower itself through successive generations of variation.

We have seen that when any given variation is in question, there is a tendency to much more rapid change after the experiment has progressed a certain number of stages.

Similarly a flower or fruit that the public at first accepts rather grudgingly may at last become so popular that it is impossible to produce it rapidly enough to meet the demand.

The Burbank rose, to be sure, did not fail of recognition from the outset. But its gaining of the gold medal as the best bedding rose at the St. Louis International Exposition in 1904 was doubtless the thing that advertised it most extensively, and led to its rather exceptionally rapid acceptance by the public.

On my own part, I look with particular pride on this rose, not so much because it received the gold medal as because competent judges everywhere have admitted that it deserved the recognition thus given it as the best bedding rose.

I have produced many plant developments that are much more spectacular than the new rose, and many that have elements of far greater novelty and interest from the standpoint of both plant developer and the general public. Yet I may be permitted to indulge in a rather exceptional satisfaction over the success of this flower for the reason that the rose is probably the most popular of

An Attractive Chilean Rose Bush

Mr. Burbank has gathered roses from all over the world, and used them in all manner of breeding experiments, both in the way of pure selection and of hybridization. Here is a highly attractive variety that came from Chile. It is but one of many hundreds, yet it has distinction in any company.

all cultivated plants, and the one that has received most attention from horticulturists of all classes, professional and amateur alike.

In attempting to introduce a new rose, then, the plant developer is coming in competition with a vast number of workers, and the product with which he operates is to be measured against an almost bewildering number of similar products that have attained a high degree of improvement. So, as I said, the plant developer may sometimes regard with greater satisfaction such an accomplishment as this, than a more spectacular achievement in plant development in a line where there is no competition.

How the Burbank Was Produced

The origin of the Burbank rose suggests in a way the origin of that very different plant development, the Burbank potato.

I was not personally responsible for either name, and the analogy between the manner of production of the rose and the potato was doubtless not at all in the mind of the dealer who christened the new flower. Still, as I have just intimated, there is a certain added propriety in the use of my name in connection with this particular rose as against a good many other roses that I have developed, because of the fact that the manner of its production suggested that of the production of the first of my important plant developments. In a word, the Burbank rose, like the Burbank potato, owes its origin to the discovery of a seed-pod on a plant that rarely produces seed.

The plant in the present instance was a Bourbon rose, of the familiar and typical species known as Hermosa. This rose very rarely bears seed, even in California, but on one occasion I discovered half a dozen seed-pods on a plant that did not differ otherwise in any obvious way from its companion plants.

I carefully treasured these seeds, and from the plants that they grew are descended not only the Burbank rose, but also the Santa Rosa, and a number of others that are less well known.

With the fact that the Burbank rose was a product of seeds thus accidentally garnered, however, the analogy with the Burbank potato ceases.

For, whereas the tuberous vegetable was produced in full perfection on one of the plants grown directly from the seeds found in the potato ball, the Burbank rose was developed only after numerous hybridizing experiments in which new blood was introduced, and new qualities were brought into the combination.

Among other roses, the strains of which were mingled with those of the offspring of the Hermosa to produce the Burbank, was the Bon Silene. And

Roses at Sebastopol

Mr. Burbank's chief rose colonies are on his farm at Sebastopol, seven miles from Santa Rosa; on the same acreage with the fruit orchards described and depicted in other volumes, and with numberless flowers to be shown in the present volume. This picture gives a characteristic glimpse of the rose colony in blossoming time.

there were at least three or four others that are similarly to be credited, although the exact pedigrees of all of them are not matter of record.

Still the initial impulse to variation which supplied the material for the new hybridizings, and was thus primarily responsible for the outcome, was given by the seeds gathered from the Hermosa. The same tendency to increased vigor and productivity and variation that we saw manifested in the case of the potato, and to which reference has been made also in the case of the sugar-cane, and of other plants that are usually propagated by division rather than by cross-fertilization, was doubtless given the seeds of the rose by a chance mingling of just the right kind of pollen—brought by some vagrant bee—with its usually unreceptive ovules.

The lesson that cross-fertilization gives vigor, and provides the materials for variation, which we have seen emphasized so many times, is here given a fresh illustration. It is a lesson that the grower of roses and other long-cultivated flowers may well bear in mind.

When the resources of selection have been practically exhausted, and a particular variety of flower has reached a static period, in which it seems to present no further opportunity for development in a given direction—say as to its odor, or its color, or its size—the plant experimenter should never forget that there still lies open to him the possibility of introducing new elements of variability, and new opportunities for improvement, through hybridization.

This, of course, assumes that the flower has not been so specialized that all its stamens have been transformed into petals, so that it becomes absolutely fertile. Such a transformation has, indeed, been effected with a good many of the cultivated flowers, including some of the roses. And the case of the Hermosa, just cited, illustrates the fact that some of our roses are practically sterile. Indeed most of them are so.

But then the flower that has ceased to have productive stamens may sometimes still have a receptive pistil, so that new blood may be introduced from a species that retains normal virility—although in general, such flowers show small capacity even for accepting the pollen.

Characteristics of the New Roses

The new Burbank rose and its sister plant, the Santa Rosa, present further object lessons in the value of cross-fertilization, in that they are not only much more beautiful than the original Hermosa from which they sprang, but that they also have qualities of hardiness and of productivity that are the token of their mixed heritage.

A Mammoth Bouquet

A number of rose bushes have grown together, to form a mammoth cluster. Of all the interesting and spectacular flower exhibits in Mr. Burbank's garden, few are more popular than the various masses of roses of many varieties.

The new races are, indeed, so hardy that they thrive in the northernmost parts of the United States and in southern Canada. They are the hardiest of all everblooming roses.

Their vigor and capacity for production of flowers are so great that they bloom incessantly throughout the season. Among all the roses there is none that excels them in the matter of almost perpetual blooming. The number of flowers produced by an individual plant is also quite out of the ordinary.

Meantime the flowers themselves are very superior in color to those of the Hermosa, and the foliage of the plants is glossy and brilliant.

These qualities were of course taken into consideration by the judges who gave the gold medal to the Burbank. But there were others which were given, no doubt, almost equal attention by the experts. One of these is the vigorous habit of growth of the plant, through which it comes about that it may be propagated almost as readily as the least fragrant weed; will root almost as easily as blue-grass, and will bloom when only two or three inches in height, and keep on blooming month after month, and year after year, if the buds are not actually frozen.

Another exceptional quality, which some practical horticulturists might regard as constituting a

Another View of the Proving Ground

Here we see another corner of the Sebastopol rose colony. The flowers here are not massed for display, but are disposed in rows for convenience of observation. As seen here, they represent transition stages; and a glance shows that they have great possibilities.

merit surpassing all the rest, is the power of resistance of the Burbank rose—which the Santa Rosa shares—to those ever-present foes of the rose family, mildew and rust.

The new roses appear to be absolutely immune to the attacks not alone of these, but of other fungoid enemies.

Their healthiness under all climatic conditions is their final and definitive quality.

Making Plants Immune to Disease

This quality of immunity to disease, while primarily due, no doubt, to the enhanced vitality given the flowers through hybridization, has been accentuated and developed by persistent selection.

In this regard, the roses do not differ from practically all other plants with which I operate. I have referred more than once to my method of developing immune races of plants, and emphasize it once more with propriety in the present connection, because, as is well known, the rose is peculiarly susceptible to the attacks of many fungoid and insect enemies.

Indeed, many a rose that would otherwise have value is so susceptible to the attacks of disease that it not only gives no pleasure to its owner, but becomes a source of infection in the garden that makes its presence a menace to other flowers.

To give plants immunity to the chief diseases to which their species is subject is, therefore, one of the prominent aims that I never overlook in the course of experiments, no matter what the particular quality that may be chiefly sought.

Therefore I make it the invariable rule, whatsoever the plant with which I am working, to examine the seedlings attentively from time to time, to note whether any of them give evidence of infection by mildew or any fungous growth.

And any seedling that is seen to be subject to mildew is at once destroyed, regardless of the value of its other qualities.

I should not regard a plant experiment successful that led to the production of the most beautiful and most fragrant and most prolific of roses, if at the same time the plant that exhibited these qualities was susceptible to mildew. Indeed, I have destroyed thousands of otherwise promising roses for the simple reason that they were subject to mildew.

I have obtained scores of climbing roses that were worthy to compete with the Crimson Rambler or the Philadelphia Rambler and other standard varieties, yet which have not been allowed to live because of their susceptibility to disease.

But the reward of this unflinching application of a principle has resulted in various types of roses that are quite generally mildew-proof.

Unnamed Beauties

Here are roses in profusion, of many varieties, all new, and as yet all nameless. It would be futile to suggest how many new varieties of roses there may be, all told, in Mr. Burbank's colony at Sebastopol. Any number of these new varieties have exceptional beauty; but only here and there one will be preserved for further experiments, and rarer still are the ones that will have the honor of introduction.

Among the ramblers just referred to, for example, by sedulous application of the principles of selection, preserving only those plants that showed themselves to have the quality of inherent resistance to the fungus, I have remaining, after thousands of their fellows have fallen by the wayside, a few rambler roses of wholly new types, which are immune to disease. This selection is not as difficult as might be supposed, because a rose that is intensely susceptible is generally attacked during the first one or two years of its existence.

Moreover, these new mildew-proof ramblers manifest, partly perhaps as an evidence of the vitality that makes them immune to disease, a capacity to produce enormous clusters of the most beautiful flowers that approach the keeping qualities of some of the everlastings.

Some of them will last at least a month, on the plant or when cut, showing thus a degree of permanency hitherto quite unheard of among roses.

Origin of the Robust Ramblers

These hardy and prolific new ramblers are largely hybrids.

There are several varieties of them representing different crosses between the well-known Crimson Rambler and such roses as the Empress of India and the Cecil Bruner and dozens of others.

Those of the first named cross often have enormous stems, with deep red hairy branches; while the hybrids of other crosses often have slender, smooth branches.

But the hybrids themselves have been interbred, and other strains that seem to give good promise were brought into their heredity, so that they have traits that do not belong to any of the original parents.

Some of these new ramblers have very large, broad crimson prickles; others have long slender ones set very closely together; still others are quite without prickles, being as smooth as the Banksias.

In color, the new ramblers vary through crimson, scarlet, and pink to snowy white. Moreover, some of them resemble the Japanese primrose in color, and, when trained on a wall, present such a unique appearance that they would not be recognized as roses when viewed from a little distance. These in particular are especially long keepers.

In explanation of what has just been said as to the uncertainties of the precise lineage of some of my roses, it may be added I have experimented first and last with a very large number of species and varieties of both commonly cultivated and wild ones, and I have not found it expedient or of any special significance to attempt to keep a pre-

The Santa Rosa Rose

This is a variety that, singled out from among thousands, was thought worthy of introduction. Moreover it was exceptionally honored in being given the name Santa Rosa. Mr. Burbank must have thought it nearly perfect of its kind, or he would not thus have honored it. The color photograph testifies that his confidence was justified.

cise record of the hybridizations after they become very complex.

For a good many years, to be sure, I kept accurate check on the various crosses.

The names of the parents used in an original hybridizing experiment were always recorded.

Later, as the cross became more complex, large numbers of species being utilized, I attempted short cuts by using numbers and letters on my labels, the key to these being recorded in my plan books.

This worked very well for a few years more. But there came a time when an experiment with a single strain of roses had been carried through so many generations that the traits of ten species or more would be combined in an individual.

At this stage I abandoned the numbers and letters, and contented myself with a general knowledge of the principal ancestors in the pedigree of any new variety, distinguishing the new variety itself by a temporary name for purposes of further record.

Thus I have, for example, grown upward of two hundred thousand seedlings from the Crimson Rambler pollenated with all the ordinary roses that are under cultivation in California. The pollen of only a few of them proved effective. But here and there a rose like the Empress of India or

A New Yellow Rambler

The ramblers, of many types, are favorites with Mr. Burbank. He has crossbred any number of them, and has produced some very notable new varieties. Here is a yellow one that has obvious distinction. As yet it has no name.

the Cecil Bruner will hybridize readily with the Rambler. Then it is possible to cross the hybrids with numerous other hybridized roses, some of which would not cross, or cross very unwillingly, with the Crimson Rambler itself.

The parents for the new crosses being themselves hybrids of complicated ancestry, it is obvious that the pedigrees in a few generations become so complicated that if one were to attempt to trace them there would be little time left for any other experiments.

So, as I said, I have contented myself with watching for results among the hybrid progeny of my roses of multiple ancestry.

There are a few of the new developments that carry strains of almost every rose generally known and cultivated up to within ten years ago, and many species not under cultivation.

Some Ancestors of the New Roses

It would be superfluous to name all the species that I have had under cultivation and have tested as to their possible value as hybridizing agents.

Even were I disposed to make such a record, it would necessarily lack finality. For there are perhaps few plants regarding which botanists are more at variance, when it comes to the matter of classifying and differentiating the species.

It is recorded, for example, that some classifiers estimate the total number of species of roses at about thirty; whereas, on the other hand, a French botanist of some authority has described no fewer than 4,266 species from Europe and Western Asia alone. Meantime, botanists in general are disposed to recognize something over 100 species, not always being able to agree as to which forms are entitled to rank only as varieties.

If there is such uncertainty among the professional classifiers, it goes without saying that the vagueness of characterization of different alleged species and varieties is far greater among practical horticulturists. There are, to be sure, a good many pretty clearly fixed types that are everywhere recognized as having individuality. But each of these is represented by many varieties, and these varieties tend more or less to run into one another. This can hardly be otherwise, considering the extent to which hybridization takes place.

So, as I said, it would be impossible to make clear record of all the species of roses that have been utilized in my experiments, even were it desirable to do so.

But it may be worth while to name a few of the more conspicuous ones that have been of exceptional service, and the hereditary factors of which have been blended and intermingled to produce the new types of roses.

The Corona Rose

This is a crimson rambler seedling, of mixed heritage, that has such altogether notable qualities as to justify its introduction. It is named the Corona. Like many of Mr. Burbank's selected ramblers, it is extraordinarily vigorous, thrifty, and prolific.

The white and buff Banksias, which are abundantly grown in California for ornamenting houses, trees, and arbors, have proved of service because they are very rapid growers, and are practically without thorns.

The *Rosa gymnocarpa,* which is indigenous to British America and California, is a pretty and graceful rose, producing fine single flowers that grow in large clusters, and having the element of hardiness that characterizes the wild plant.

The Chinese rose, in numerous varieties (*Rosa Chinensis*), and the Japanese rose (*Rosa rugosa*), have made their influence felt in many hybrids. So also has the Wichuriana. The seedpods of the Japanese species are unusually large and handsome. The hybridization of the Japanese rose with the Bon Silene and with other strains, including the Hermosa, produced a number of admirable roses that I have introduced, including the Pipette, Coquito, and Peach Blow.

The General Jacqueminot, one of the best known of the hardy perpetual bloomers, is itself a hybrid—as indeed are all other cultivated roses, no doubt, could we know their precise pedigree.

It is a hardy and prolific plant, and its qualities are curiously prepotent when it is crossed with other varieties. This applies not merely to the form and color of the flower itself but to the entire

Chilean Wild Roses

These Chilean wild roses have been carefully selected in Mr. Burbank's garden, but otherwise are unmodified. They will be used in hybridizing experiments; and not unlikely they will instill their qualities of hardiness and prolific bearing into their hybrid progeny.

structure of the plant. Its chief characteristics seem to have peculiar prepotency or dominance. But of course the latent characteristics of the variety with which the Jacqueminot is crossed may reappear in later generations.

In striking contrast with the virility of the Jacqueminot is the approximate sterility of the hardy old-fashioned Persian rose.

This has blossoms of the handsomest yellow color, and on this account was regarded as a desirable parent for hybridizing experiments, notwithstanding that it blooms for only a short season in the early summer. But not only does the Persian rose itself fail to produce seed, but its pollen seems to be sterile when applied to the pistils of other flowers or fails to reveal its character in the seedlings. For many years I attempted to hybridize the Persian rose with the Tea rose, Perpetuals, Banksias, Multifloras, Bourbons, Wichurianas, and many others, but in no case did I succeed in making a useful combination. Nor was the experiment more successful when an attempt at a reciprocal cross was made. The pistils of the Persian rose failed to respond to the stimulus of pollen from whatever source. So, of course, there was no strain of the Persian rose in any of my hybrids. This variety has seemingly reached a stage where it can apparently be perpetuated only by division.

Enough has been said to show that the rose is a very tractable flower. Indeed, the very fact of the number of its species and varieties sufficiently attests its variability and receptivity.

Moreover, the rose is entitled to be considered pre-eminently the universal flower. It doubtless excels all others in popularity and it differs from most others in that it is prized equally in its different varieties for its form, its color, and its fragrance.

As to all of these, to be sure, approximate perfection appears to have been attained with a good many varieties of roses. Yet the fact that new varieties are from time to time put forward shows that there is always opportunity for improvement. I have emphasized certain directions in which the improvement of the many varieties is possible—notably in the matter of hardiness and resistance to disease.

The Chance for New Roses

But, in point of fact, the list of qualities that are taken into consideration by the connoisseur as well as the commercial grower of roses is so extensive that there is opportunity for development through selective breeding of almost any existing variety as to one or another trait that it lacks. Abundance of bloom, lasting qualities of the flower, beautiful buds, long stems, handsome foli-

Blue Roses

Few types of experiment appeal more strongly to Mr. Burbank than those directed toward the bringing out of some obscure quality or submerged trait of a flower, such, for example, as an unfamiliar or unusual color. No one needs to be told that a blue rose is an anomaly. The color photograph shows Mr. Burbank's success in causing the rose to take on this unfamiliar color.

age—these are qualities in addition to the fundamental ones of hardiness and resistance to disease that must be taken into account in estimating the value of a rose. Then there is one other characteristic of the rose which has hitherto scarcely been considered by anyone, yet which seemingly lies within the possibility of development. This is the matter of increasing the amount of pulp that encases the seed pod of the rose. So much attention has been given to the flower that no one has given heed to the fruit. But it is familiarly known that the rose belongs to the same natural order with the apple, the pear, and our other chief fruit growers of the orchard. So it is a reasonable assumption that this plant could be educated, were sufficient attention paid to the matter, to produce an edible fruit.

Even as the case stands, the fruit of some of the wild roses is sometimes eaten by children, though its proportion of pulp to seed is so small as to be almost negligible. And what has been accomplished with other members of the tribe makes it seem probable that the pulp could be developed and the seed correspondingly decreased until the fruit became quite transformed.

I have said that the rose is the universal flower. Doubtless it already takes first rank among the flowers that man has brought under cultivation.

But if it could be made to supplement its wonderful blossom with a really valuable edible fruit, the pre-eminence of the rose among all the plants that man has placed under cultivation would be still more firmly established.

—There is a time element in the introduction of a new flower or fruit. In fact, no new plant development could be expected to make its way except very gradually at first; although it gains momentum with great rapidity after a time.

Haemanthus Blossoms

The Heamanthus or blood lily is a South African bulbous plant, of which there are many species, belonging to the same family with the amaryllis. It will be seen that the flowers of this particular species are very attractive in themselves; but their chief value in Mr. Burbank's eyes is their possible availability for hybridizing experiments with some of their relatives. We shall see that Mr. Burbank has made very notable experiments in hybridizing members of this family.

Accomplishing The Apparently Impossible With the Amaryllis

Wonderful New Blossoms Nearly a Foot in Width

I TAKE it that a flower ten to twelve inches across occupies about the relative position among flowers that a man ten to twelve feet high would occupy among men.

Doubtless you have never seen a ten-foot giant, for I believe there is no record of any human being of that size. And I presume that you have never seen a ten-inch flower, unless one of my giant amaryllis blossoms has come to your attention.

At all events, it is rare indeed that any flower here in the temperate zone attains even approximately such a size. The blossoms of some of my new artichokes spread out to the same dimensions as Lilium auratum, and exceptionally there may be an individual blossom of some other species that has a spread that approaches the same mark.

In general, however, as everyone knows, flowers are accounted large if they exceed six inches in diameter, somewhat as a man is accounted large if he exceeds six feet in height.

But several of my new giant amaryllis, with their ten-inch spread of petals, are very anomalous and extraordinary flowers. As I said before, they occupy among flowers a position not very different from that which would be occupied among men by a ten-foot giant.

If no ten-foot giant has ever appeared, it is probably not so much because the human race does not have potentialities of producing such a specimen, but that experiments in selective breeding of men for the quality of size, comparable to the hybridizations that produced the giant amaryllis, have never been carried out during a series of generations.

Breeding Giants

Everyone has heard of the attempt that was once made by a Prussian king to develop a race of giants by selective breeding.

As the story goes, the king marshaled all the tall men he could find into a special regiment, and sent inspectors over his kingdom in search of tall women as wives for his tall soldiers. He intended thus to produce a royal bodyguard of giants that should be the astonishment of the world.

And no one who has followed out a series of experiments in selective breeding of plants, and

A Burbank Crinum

This is a hybrid between the crinum and the amaryllis, which has developed a bulb of extraordinary size. Some specimens have bulbs larger than a man's head. The flowers are not so notable, but they have interest because of their origin.

who realizes the essential identity of the principles of heredity, applied to men and plants alike, will doubt that the would-be developer of a race of giants was on the right track.

He was starting out in just the way that I started when aiming to produce a race of amaryllis plants that would grow gigantic flowers.

But even had the royal experiment in man-breeding been carried forward by the successors of the originator of the idea, it would have been a long time before a giant appeared among the royal guards that overtopped his fellows in such proportion as the giant amaryllis outspreads its companions.

For there is a time element in these breeding experiments that cannot be ignored; and the units of measurement are not years but generations.

In the case of the amaryllis a generation varies somewhat with different species and varieties, but frequently is not more than two years. In other words, many species of amaryllis will produce seed in their second year, when grown from seed. And at most three or four years suffice to bridge the gap between successive generations.

But a human generation spans a gap of something like a quarter of a century. As a rule the most vigorous and healthy offspring are not born until their parents are at least twenty-five years old. So in making an analogy between the breeding of a giant amaryllis and the breeding of a giant man, it is necessary to bear in mind that ten generations of the amaryllis are compassed in the span of a single human generation.

In other words, the plant developer may logically hope to produce with his amaryllis, in a period of twenty-five years, a development comparable to that which the royal breeder of giants could hope to have duplicated only in the reign of some successor, perhaps of another dynasty, 250 years later.

It has taken at least ten generations of hybridizing and selection to produce my giant amaryllis.

So we may assume that if the project of the Prussian king, which was inaugurated about the middle of the eighteenth century, had been systematically followed up by his successors, there might be a possibility that a ten-foot giant would have appeared among the descendants of the giant guardsmen about the year 2,000 A. D.

We may add, however, that it would probably have been necessary to extend the search for giants, to breed into the strain of royal guardsmen, far beyond the bounds of Prussia.

Reasoning still from plant analogies, we may assume that the full measure of possible development in the direction of the ten-foot giant would

Pollenizing the Amaryllis

After many years of failure in attempting to improve the amaryllis, Mr. Burbank was successful only when he had learned the peculiarity of this flower, which is clearly shown in the color photograph print above. The pistil, as will be seen, is longer than the stamens, and appears at first with a stubby end, which later divides into three lobes. In the case of the amaryllis the pistil does not become receptive until the flower itself is withered, as is shown in the upper left-hand corner above. Only when the flower itself has faded does the pistil open up its three sticky lobes, and only then can pollenization be accomplished.

have been attained only when men and women of widely divergent races—Turks, Persians, Hindoos, Negroes, Patagonians, South Sea Islanders—were brought into the coalition and mingled with the European races.

And in making this illustration I am only seeking another way of emphasizing the truth which we have seen illustrated in many fields, that the widest possible range of variation, and therefore the greatest possible opportunity for development along any given line, can be stimulated only by the hybridization of species or varieties that are divergent almost to the limits of affinity—using the word affinity in the sense defined in our earlier studies of cross-fertilization.

It was thus that my gigantic walnut trees were produced, as the reader will recall.

It was thus that the fruit of the little beach-plum was magnified from the size of a berry to that of a nectarine.

It was thus that the giant among small fruits, the Phenomenal berry, was brought into being.

And such also was the origin of the giant spineless cactus plants, and of numerous other plant developments in their way quite as remarkable, even if not always so spectacular.

Flowers Versus Men

With the breeding of a giant race of men, we are of course as little concerned as the successors of the Prussian king who inaugurated the short-lived experiment.

There is no real demand for a race of human giants. They would not fit into the scheme of things. Houses and carriages and furniture are not built for them. At best they would be but curiosities, and the world produces quite enough human curiosities by accidental breeding without starting out systematically to secure them.

But it is quite otherwise with plants. Here the production of curiosities—that is to say, plants that differ conspicuously from their fellows of the same species—is an object considered quite worth while, because these plant curiosities, provided the anomaly they present has to do with some inoffensive quality, give pleasure and profit to plant lovers everywhere, and add to the sum total of human happiness.

Such a product as the giant amaryllis, for example, excites universal admiration.

The mammoth flower is a thing of genuine beauty, regardless of size; and if mere size does not in itself accentuate the beauty, it at least does not detract from it, and it brings to the beholder an added sense of wonderment that enhances the satisfaction with which the flower is viewed, and gives a pleasurable stimulus to the imagination.

Chilean Wild Amaryllis

In conducting his very extensive experiments with the members of the amaryllis tribe, Mr. Burbank has sent to all parts of the world for new species and varieties. Here is one from Chile which has been utilized, along with many others, in crossbreeding experiments.

So it may be assumed that the task of developing this unusual flower was a task quite worth the doing. It called for many years of earnest effort, of patient waiting, and of intelligent selection. But the results fully justify the effort.

The story of the difficulties encountered in the early day of my experiments with the amaryllis in effecting cross-fertilization of the flower has been told in an earlier chapter. The reader will recall that I was at first unaware that the pistil of the flower matures at a later date than the stamens; hence that for a time I applied pollen carefully to the pistil of flower after flower before it had attained the receptive stage, and so failed to get any results.

But in due course I learned that the pollen must be taken to the pistil of a flower that has shed its own pollen several days earlier and when I understood this simple feature of the technique of cross-fertilizing the amaryllis, I had no further difficulty as to that part of the experiment.

Materials for the Experiment

The material with which I began my experiments consisted of a few familiar species of the genus *Hippeastrum*. Properly speaking, this genus should not be called amaryllis, as that name belongs to an allied genus with which we shall make acquaintance presently.

But the various species of Hippeastrum are known universally as amaryllis to the florist, and it will be convenient here to follow the general custom of applying that name to all the members of allied genera that are grouped together horticulturally and everywhere referred to as if they were of one tribe.

We shall see presently that the members of the different genera, including not only the hippeastrums and the genus Amaryllis itself, but also *Sprekelia, Crinum,* and *Brunsvigia,* have been variously hybridized in the course of my experiments. Thus the affinity suggested by their similarity of appearance is demonstrated, justifying at least in a measure the convenient horticultural custom of applying the familiar name amaryllis to all of them.

Peculiar interest and probably exceptional importance attaches to the fact that the first group of plants of this tribe with which I experimented included the forms of cultivated amaryllis known as *Hippeastrum Johnsoni, H. vittatum,* and *H. reginae.*

The significance of this lies in the fact that although these are plants of quite different characteristics, so that they everywhere rank as good species or fixed varieties, yet in point of fact the one first named, Johnson's amaryllis, is a hybrid

Peruvian Amaryllis

This is another member of the amaryllis tribe that has come to Santa Rosa to enter into Mr. Burbank's experiments in developing this remarkable race of flowers. This Peruvian species is unnamed, and perhaps was never elsewhere under cultivation.

that resulted from the union of the other two species.

The hybridizing experiment through which this new form was produced was made as long ago as the year 1799 by an English amateur gardener named Johnson, whose business of watchmaking had presumably given him facility in the performance of such a manipulation as is involved in the hand pollenizing of flowers.

The hybrid form thus produced not only took its place as a recognized horticultural variety, but was botanically recognized as entitled to a distinctive name. It has maintained its place alongside the parent forms during the century and more since it was first developed. Doubtless there have been some modifications in the original characteristics of the hybrid through selection, but, for anything we know to the contrary, Johnson's amaryllis retains to this day the essential characteristics of the hybrid developed by the watchmaker through the union of the two other species.

Inasmuch as the amaryllis is often grown from seed, it may be assumed that any given specimen of Johnson's amaryllis in existence to-day, including of course those with which I first experimented, is a generation or more removed from the original hybrid. Not so many generations as might at first thought appear, for the usual method of propagation of the amaryllis is by bulbs. But now and again new plants would be raised from the seed, and it would be natural that the florist should select for seedlings the best and most typical representatives of the species. So we may assume that the specimens with which I worked represented a fixed type of hybrid inbred for a number of generations, yet still carrying the new combination of hereditary factors originally brought together through hybridization of the other forms, already named as *H. vittatum* and *H. reginae.*

VERY MIXED PEDIGREES

So when I began hybridizing experiments, and crossed the *H. Johnsoni* with *H. vittatum,* I was in reality making a union of a hybrid with one of its parents.

The closeness of affinity of the two would insure ready fertilization. But, on the other hand, the balance of hereditary factors that had been attained in the hybrid would be disturbed and the immediate offspring would really represent second-generation hybrids, of which one parent was at the same time a grandparent.

The disturbing influence of this hybridization was manifest enough from the outset, and the tendency to variation thus initiated was accentuated in the next generation, which brought into the cross another species known as *H. aulicum.* It

A Cluster of Giants

This is a bunch of amaryllis flowers, of one of the Burbank giant varieties. The appearance of the bouquet may be realized, when it is understood that no one of the blossoms is less than 8 inches in diameter.

was still further accentuated in the next generation, when I used as hybridizing agent *H. Reginea,* which, it will be recalled, was one of the original parents of *H. Johnsoni.*

Thus, having started with a hybrid, I had produced three additional generations of hybrids, in which the parent forms were used and a different species added, so that my fourth-generation hybrids had the strains of three species curiously blended.

Persons who care for matters of genealogy might find it of interest to attempt to unravel the pedigrees of these fourth-generation hybrids which had for one parent the species *H. reginae* and for the other a hybrid whose parents were born of a union of *H. aulicum* and a hybrid of *H. Johnsoni* and *H. vittatum;* recalling that *H. Johnsoni* itself is the offspring of the progenitors of *H. reginae* and *H. vittatum.* The questions of cousinship involved in such a union are much too complex to interest anyone but the antiquarian.

At all events they need not be untangled by the plant developer. For him it suffices to recall the names and characteristics of the various species and to concern himself with such selections among their offspring as will produce races blending these characteristics in new and desirable combinations.

But, indeed, the experiment became even more complex as it proceeded to additional stages.

For by this time I was in possession of several other species of amaryllis, and these also were worked into the combination by hybridizing with different members of the fourth-generation hybrids already introduced.

The new species would be crossed with various of the hybrids to accentuate certain qualities of size of flower or color or prolific bearing; and the new hybrids thus produced would in turn be interbred, until the tangled web of their heredity was quite beyond unravelling.

Getting Results

But at each stage of such a series of experiments the plant developer of course watches for results and is guided by results.

He has learned by this time of the tendencies to variation that exist. He has gained a clear idea as to the various new races that he hopes to develop. And he is able, through selection of plants for his new matings, and through selection among the seedlings of the ones from which to save seeds, to direct the currents of heredity into desired channels.

As I have elsewhere phrased it, the plant experimenter becomes an effective part of the environment. He becomes the most important

A Rare Chinese Amaryllis

Flowers of the amaryllis tribe are found in the Orient, no less than in the tropical regions of both continents. This is a rare variety that was sent to Mr. Burbank from China. Attempts will be made to blend its strains with those of various other allied plants from remote regions.

agent in that process of selective breeding through which the evolution of new forms of plant life is brought about.

In the present instance, the tendency to variation that was manifested from the outset, was accentuated generation after generation until, after about twelve years of work, I had a colony of mixed hybrids showing wide departures from any of the ancestral forms.

Some of the new forms had very large bulbs, and grew plants of exceptional strength, bearing blossoms of unusual size.

I had, of course, selected for strong stalks, broad leaves, and abundant bearing and for rapid production of bulbs and ready growth, as well as for large flowers with wide petals of brilliant colors.

The original species had usually borne small bulbs, and put out only two or three offset bulbs in a season.

The bulbs of the new hybrids sometimes weigh more than six pounds.

The stalks that grow from them are of correspondingly increasing size and strength. And instead of putting out three or four new bulbs in a season, these hybrids sometimes multiply so rapidly as to produce a bulb every month, and in the case of some forms a new bulb every week.

That is to say, the most prolific species will produce fifty new bulbs in a year, instead of the three or four of the original species.

In point of prolific bearing, there is a corresponding contrast. The original species had seldom more than two or three stalks to a bulb, with four or five flowers in a cluster.

The new varieties often produce four or five stalks to a bulb, where they have remained in the ground for a few seasons, with as many as twelve flowers to the stem.

The enhanced fecundity of the new forms is supplemented by their tendency to early bearing. They will sometimes bloom the second year from the seed, and on the average they bloom in three or four years. The old forms sometimes require six or eight years to come to maturity. As Prof. De Vries has said, I have pretty nearly cut in half the time from seed to blossom in the amaryllis.

But of course the most conspicuous contrast of all is in the flowers themselves. In the original species, the largest flowers seldom attain a diameter of more than five or six inches. The new giant species, as already stated, often produce flowers that are ten inches or even more in diameter.

There is considerable variation even in the same race, dependent in part on the size of the

A Bed of True Amaryllis

This is the Amaryllis belladona; a true amaryllis, therefore, unlike most of the plants that go by that name in the catalogs of the horticulturist. The amaryllis of the gardener is usually a plant of the genus Hippeastrum; but the name amaryllis has been so generally given to the plants of this genus that it would be useless to attempt to change the nomenclature.

bulb from which the individual stalks grow. This should always be understood by persons who grow the amaryllis. A bulb that has been ill-treated in its first year, and has not attained large size, will not produce a large flower, even though it have the hereditary factors for large blooming.

To produce the largest flowers, we must give the plant a full supply of nourishment, and thus develop a large bulb. The gigantic flowers appear only on stalks that grow from gigantic bulbs.

But of course no conditions of nourishment and no amount of forcing can produce bulbs or flowers of gigantic size unless the hereditary strains have been properly blended. And this blending, as I have just pointed out, involved years of experiment, and the bringing together of the traits of many different species.

I had experimented with the amaryllis for about fourteen years before I obtained varieties that seemed worthy of introduction. And the new giant varieties are the product of many additional years of experimentation.

The variety introduced under the name Profusion several years ago was at that time the most abundant bloomer known. Its blossoms were also relatively large, and it had many points to commend it.

But the races that have been developed more

A Burbank Amaryllis

This is one of Mr. Burbank's giant amaryllises (really a Hippeastrum), produced by hybridizing various species. These plants have been extensively hybridized for more than a hundred years, and all the varieties now under cultivation are crossbred.

recently, through the further blending of hereditary strains, excel this markedly in every regard. Indeed, the newest acquisition to the ranks of the Giant amaryllis have advanced surprisingly upon their recent forebears.

And when the gigantic ten-inch trumpet of the new variety is put beside even the largest flowers of the remote ancestral type, the contrast is so striking as to seem to suggest things of a quite different order.

Still Wider Hybridizations

Having reached something like the limits of variation attainable through hybridization of the different species of Hippeastrum, I extended the experiments by crossing the new amaryllis hybrids with plants of other allied genera, notably with Sprekelia and Crinum.

The Sprekelia is represented by a single species indigenous to Mexico and sometimes called the Jacobean lily. It has long, slender, strap-shaped leaves, and a showy crimson flower of an unusual form that suggests a bird in flight.

I have worked on the Sprekelia more or less for twenty years, raising probably a hundred thousand seedlings. But I succeeded only once in hybridizing the plant, with the production of fertile offspring.

The hybrid amaryllis that made union with the

Jacobean lily was my new *vittatum* type, having pale red flowers striped with white. Only a single hybrid of this union bloomed, but from this a number of seedlings were grown.

The hybrid offspring of these plants of different genera had long, narrow, strap-shaped leaves much like those of Sprekelia (the pollen parent), but the blossoms were very much larger than those of that plant, and they had very curiously twisted petals, unlike those of either parent.

As might be expected in the offspring of plants so widely separated, the hybrids were almost infertile. As already noted, only a single variety bore blossoms, and although the blossoms were produced almost continuously throughout the summer, there was seldom any seed, and it was with difficulty that I succeeded in raising seven or eight seedlings.

In a more recent year, however, I succeeded in hybridizing many blossoms of Sprekelia with the pollen of an improved hybrid Hippeastrum, and secured about 800 seedlings which showed the characteristics of the other hybrids obtained by the reciprocal cross of the same species. The second generation hybrids, and also those of the third generation, showed a strong tendency to revert back to the giant hybrid species of amaryllis, rather than toward natural species.

Yet Another Burbank Amaryllis

When Mr. Burbank's amaryllis experiments were at their height, his colony of these plants was regarded as the finest to be seen anywhere in the world. Some of his hybrids took on gigantic growth, producing flowers almost twelve inches in diameter. They made a gorgeous display in blossoming time.

ON THE AMARYLLIS

The bulbous plants of the genus Crinum appear to be somewhat closely related to the Hippeastrums. There are two species known as *Crinum moorei* and *C. longiflora* that grow in Northern California, and there are numerous other species, some of which are evergreens.

I have grown about twenty species, some of them of tropical origin. Numerous crosses were made among these species until I had a crossbred strain of Crinums of ancestry as complex as that of my Hippeastrums. The seed parent of a larger proportion of the hybrids was the species known as *Crinum Americanum,* but a few were grown from the seed of *C. Anabilis* and *C. Asiatica.*

In the various crosses, the traits of the species of temperate zones appeared to be prepotent or dominant.

Interesting hybrids were produced by crossing the Crinums, not with the members of the Hippeastrum colony (this proving impossible), but with the form of true amaryllis known as *Amaryllis belladona.*

The hybrids thus produced were a very curious lot. They seemed undecided whether to take on the flat, strap-shaped leaves of the amaryllis or the tunicate leaves of the other parent. The compromise led to the production of a leaf with a long curious neck.

The flowers, like the plants themselves, may be described as a balanced combination of the qualities of the two parents. They are smaller than the flowers of the amaryllis, and more tubular, and in color they vary from the white of the male parent to the deepest rosy crimson, light pink being the most common color. The flowers of the amaryllis vary from rosy pink to crimson.

Although the hybrids bloom somewhat abundantly, they never produce a seed. The hybrid plants may of course be propagated indefinitely from the bulbs, constituting thus a permanent variety. But they evidence the wide gap between their parents in that they are sterile.

A Look Ahead

It will be obvious from all this that the colony of amaryllis plants, with its hybrids of intricate lineage, involving not only many species, but four genera, is a collection of plants of altogether exceptional interest.

From a mere horticultural standpoint, it is considered by experts to be the best collection of amaryllis in the world. Not only has this colony the greatest diversity of forms but the most extraordinary individual plants.

Experts of both Europe and America who have visited my grounds are agreed in pronouncing my galaxies of amaryllis far superior to any to be

A Double Amaryllis

Among the almost numberless variations that occurred among the specimens in Mr. Burbank's hybrid amaryllis colony were some that produced double rows of petals. Here is one that might readily become the progenitor of a race of amaryllis in which the petals altogether take the place of the reproductive organs, as is the case with some varieties of double roses and dahlias. Even at the present stage, this is an interesting anomaly.

seen elsewhere, not only in size but in rapid multiplication and general effectiveness.

As with any plant colony that has been brought to such a degree of variability, with only relative fixation of many new combinations of characters, there are possibilities of further development that can only be realized in later generations. The number of new combinations that might be made among the complex hybrids of different types is quite beyond computation. But it may safely be predicted that some of these combinations will produce results even more striking than any hitherto attained.

As an inkling of some of the expected developments that as yet are only at their beginnings, I may add there is among my plants one that bears a sixteen-petaled flower, and which is otherwise exceedingly handsome. This did not breed true as to the production of excess petals, but there is little doubt that by selective breeding it will be possible to produce a double amaryllis which will be an entire novelty.

In the matter of hardiness also, there is opportunity for great improvement. My amaryllis plants are grown out of doors, the seedlings being started in the greenhouse in boxes very much as other bulbous plants are started, but not in a high temperature. There is opportunity, however, to increase their hardiness by selection, or by crossing with some hardier species.

It is true that the hybrids of Crinum and Amaryllis have hitherto been sterile, but there is reason to hope that other combinations might be found that would produce fertile offspring.

These and such like developments, however, await the experiments of future seasons and future experimenters. But, even as it stands, the colony of bulbs of the amaryllis and its allies constitutes one of the most interesting groups of plants anywhere to be found.

—If no ten-foot giant has ever appeared, it is probably not so much because the human race does not have the potentialities of producing such a specimen, but that experiments in selective breeding of men for the quality of size, comparable to the hybridizations that produced the giant amaryllis, have never been carried out during a series of generations.

A Shirley Poppy Variation

The Shirley poppy is a flower developed within recent years by an English clergyman, who found a solitary flower of the scarlet corn poppy that had a very narrow edge of white. By selective breeding he produced the poppies of many colors now familiar under the name of Shirley. The specimen here shown illustrates the tendency of the flower to take on new color variations.

Bringing Forth an Entirely New Color

And Other Important Work With the Poppies

FOR some reason blue is not a favorite color among flowers.

There are notable and conspicuous exceptions, of course, but for every species of blue flower in nature there are hundreds of flowers that are yellow, or red, or white.

Presumably the color blue does not attract the eye of the insect so strikingly as do the other primary colors. Flowers are not green for the obvious reason that, since leaves in general are green, flowers of that color would blend with the foliage, and thus defeat the primal purpose of the floral envelope.

And, no doubt, blue is a color nearer to green in its hue or general aspect than are the reds and yellows.

So it is perhaps not surprising that natural selection has weeded out the blue flowers and given us an abundance of red and yellow and white ones.

Of course, there may be some underlying reason associated with the chemical character of the different pigments that helps to account for the relative scarcity of blue flowers. But, as to this, no one at present has any definite knowledge, for the chemistry of the pigments, and the underlying differences between the pigments of different colors, in the petals of flowers are very little understood.

But, whatever the explanation, the fact of the scarcity of blue flowers is patent enough. Where a flower has adopted the blue pigment, it may hold to it tenaciously. But, on the other hand, there are thousands of blossoms that show great variation in color, ranging through the various tones of scarlet and crimson and pink and orange and yellow, apparently quite without discrimination, yet avoiding blues of every type.

A Blue Poppy

Conspicuous among the flowers that show this wide range of variation in color, and yet never by any chance have been known to produce a blue flower in the state of nature, is the familiar Poppy.

So the production of a blue poppy in my gardens, through a long series of selective experiments, may be considered one of the most striking

Another Shirley Poppy Variation

The Shirley poppy differs from its wild progenitor in that it has varied from the original red color to a pale pink and even to a pure white; and in particular in having lost the black central portion of the flower that is so characteristic in the wild corn poppy. The true Shirleys are characterized by the entire absence of black—they have not the smallest fleck of it about them. But the mixture of color-factors in their germ plasm is revealed in the striking tendency to variation in unpredictable directions, of which this specimen gives a good illustration.

of the minor plant developments accomplished there. There is no record of a true blue poppy ever having been produced elsewhere.

The blue poppies bloom toward the last of May or early in June each year, furnishing a spectacle that never fails to excite the interest of visiting florists.

The story of the production of the blue poppy is a comparatively simple one as to its chief outlines. That is to say, the work that was directed exclusively to the production of a flower with this color was carried out without any complications of hybridizing, solely as a problem in selection.

A measure of success was attained in the course of five or six years after the problem had definitely presented itself.

But, on the other hand, it should be explained that the specific idea of developing a blue poppy came only as a sequel to a long series of very arduous experiments in selective breeding through which the ancestral stock that finally produced the blue poppy had been developed. And it is more than probable that the preliminary experiments, although aimed at quite different purposes, were absolutely essential to the segregation of hereditary factors in the plants of my poppy colony that made possible the final development of the flower with the anomalous color.

Therefore, it will be necessary, as preliminary to a specific account of the quest of the blue poppy itself, to give somewhat in detail the story of the development of the ancestral strains of poppies of varied but more usual colors.

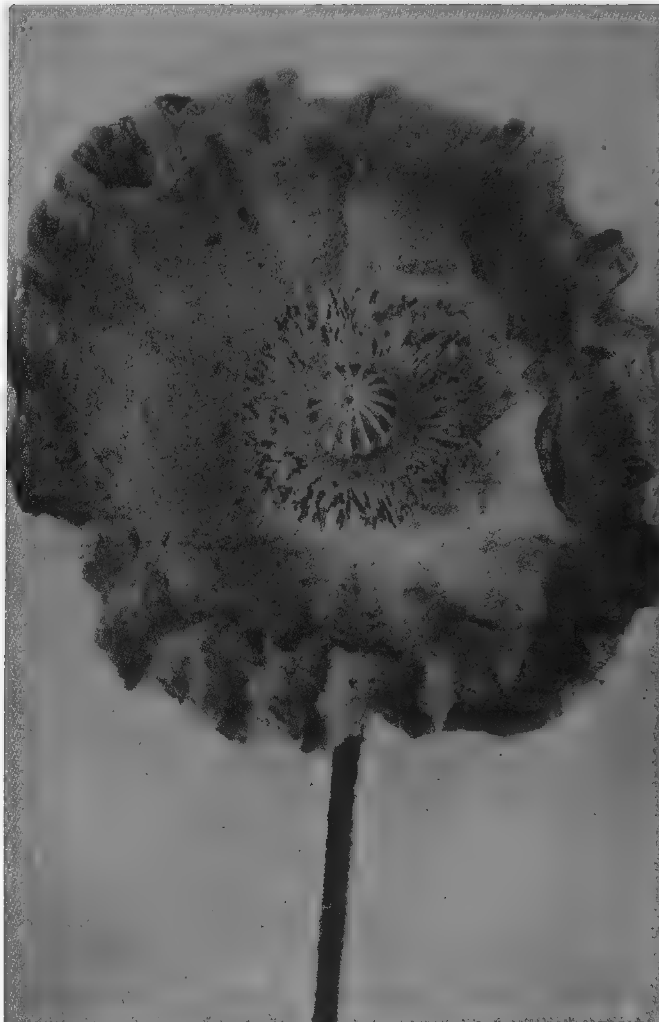
Origin of the Shirley Poppy

The poppy from which the blue flower was developed is of the variety known as the Shirley poppy.

This is one of the most interesting and beautiful varieties of the species *Papaver Rhoeas,* the corn poppy of Europe.

The peculiarity of the Shirley in which it differs from the wild form of field poppy is that it varies in color from the original red to a pale pink and even to a pure white; and that the original black central portion of the flower has been changed to yellow or white. The last-named characters are the distinctive ones. The true Shirleys never have the smallest particle of black about them. They may be scarlet or pink or white or variously flecked. But they have no black about them, and they were never yellow, until pale yellow and pale orange shades have recently arisen.

This beautiful variety gains enhanced interest when we learn that it was developed as recently as about the year 1880, in the garden of an English clergyman, the Rev. W. Wilks, through a series of



Yet Another Shirley

Once a flower manifests a tendency to vary, there seems to be no limit to the range of its variations. It would be hard to say just what combination of hereditary factors in the germ plasm of the original Shirley led to its peculiar departure from the traditions of its tribe. But man's selective judgment enabled these submerged color factors to make themselves manifest, as they doubtless would not have done without his aid; with the result that a strikingly modified flower was produced in the course of a few generations.

selective experiments of precisely the character so often illustrated in the course of our present studies.

It appears that Mr. Wilks discovered in a field of the corn poppy of the usual scarlet color, a solitary flower that had a very narrow edge of white. He marked this flower, saved the seed of it, and the next year carefully watched the seedlings. Out of perhaps two hundred he found four or five on which all the flowers were edged with white.

The best of these were marked, and their seedlings were selected from in turn.

In successive years a large proportion of the flowers gained an increasing proportion of white to tone down the red, until they arrived at a quite pale pink, and finally one plant was found that was pure white.

The attempt was then made by similar selection to change the black central portion of the flower to yellow or white, and in due course this also was accomplished.

The new strain being fixed by selection, the Shirley poppy, which has come to be one of the most popular of flowers, was given to the world.

It appears, then, that the Shirley poppy is a variety that has been specially selected within comparatively recent years, with an eye to the one problem of color modification. It therefore represents a strain of plants in which there is a curious mingling of hereditary factors for color. It is a fixed variety, at once recognizable, yet the different flowers that resemble each other to the point of approximate identity as to form and botanical features may be scarlet or pink or white or variegated, and all these colors may be represented in the plants grown from a single lot of seed, and sometimes in a single individual flower.

Even as to the matter of the black center which characterizes the original corn poppy, the Shirley shows a tendency to reversion. Now and again flowers appear that have black spots at the base of the petals. These, however, are rigidly excluded by the florists in selecting seed.

Other marks of tendency to variation in the Shirley are the uncertain length of the stem, which may be very short or very long, and a propensity to doubling of the petals, which is regarded as a defect. Moreover, there is sometimes manifested a tendency to a crimson hue that is regarded as reversional, and has to be eliminated by the careful flower grower.

Perfecting the Shirley Poppy

All these marks of a tendency to variation, together with a history of the development of the flower, marked the Shirley as a plant suitable for further experimentation. So about twenty years

A Santa Rosa Shirley

A flower with such tendency to vary as the Shirley poppy has manifested naturally appealed to Mr. Burbank. He has experimented very widely with this variety of poppy, and has modified it very markedly, particularly with reference to the texture of its petals. By rigid selection among many thousands of specimens, conducted year after year, Mr. Burbank has so modified and improved the Shirley that seedsmen usually sell his varieties as the Improved Shirley poppy, or the Santa Rosa strain of the Shirley poppy.

ago, at a time when the Shirley was a comparatively new flower, I commenced a series of experiments with this variety, securing seed from every available source.

I was somewhat astonished and disappointed to find that, in spite of the diversified color scheme of this flower, there was a very striking uniformity among the plants produced from various lots of seed. Everywhere there was a strong tendency to revert to the original scarlet color, but otherwise the colors were relatively fixed. Attention was chiefly attracted to the form of the petals, however, which seemed rather lacking in gracefulness, being too flat and without character.

With the thought of modifying the petal and thus beautifying the flower, I commenced the most rigid selection, choosing the first year only four or five plants out of many thousands, and from the progeny of these reselecting from season to season.

I chose the flowers that showed the lighter shades of scarlet, crimson, and pink, and those that were altogether white.

Attention was given also to the selection of large flowers, and in particular to those that had the most delicate petals, but firmness of texture and any suggestion of waviness was joyfully welcomed.

For many years I kept up this selection, rais-

Bush of Santa Rosa Shirleys

The modifications both in the petals—which have been given a very characteristic delicacy of texture, combined with firmness—and in the stem of the plant and its manner of growth effected by Mr. Burbank are so striking that it has been suggested that his type of Shirley poppy should be given a new name. He prefers, however, to retain the name Shirley, in recognition of the work of the experimenter who first produced the variety.

ing large quantities of poppies, and having the aid of four or five men in scrutinizing all the flowers in the field for an hour or two each morning during the blooming time, that no specimens showing favorable variation should be overlooked.

At first the progress was very slow. It was easy to find specimens that were semi-double and those that showed the black spots. But there was very slight tendency to crimping of the petals.

As usual in such cases, however, there came a time when progress seemed much more rapid.

Thenceforward the work was encouraging and full of interest, and in a few years more a most beautiful strain of poppies had been produced which presented almost in ideal combination the various qualities for which I had been selecting. Those that were not pure white showed an astonishing variety and a beautiful blending of the more delicate shades of red and pink.

The plants were graceful in form and of uniform height, and, most important of all, the petals of the flowers were of the thinness and almost of the texture of tissue paper, yet of firm texture, and artistically waved and crinkled, in strong contrast with the smooth petals of the original varieties.

This plant was introduced through a prominent seedsman as an "Improved Strain of Shirley

Poppy," and later when still further improved as the "Santa Rosa Strain of the Shirley Poppy." The modifications are so striking that various horticulturists have suggested that the plant is entitled to rank as a new variety. But I preferred to recognize the variety from which the new plant had been developed by retaining its name.

Coming of the Blue Poppy

It has repeatedly been observed that no flower or fruit is or can be developed beyond possibility of further improvement. However closely a new form may approximate the ideal at which the plant developer aimed there are always variations that suggest new possibilities that perhaps were not contemplated at the outset of the experiment.

And the improved Shirley poppy was no exception to this rule. As work continued with the new flower, the form of its petals modified until they were exquisitely delicate, and its colors blended until the most artistic and delicate shades were predominant, attention was attracted one day to a specimen growing among the thousands that revealed a color a shade different from any other previously seen.

On inspecting this flower I seemed to detect, underlying the normal color, a smokiness suggestive of a half-concealed blue pigmentation.

Naturally this was carefully guarded and the

A Characteristic Specimen

This picture gives a very good idea of the characteristic texture of petals in the Burbank improved Shirley poppy. Mr. Burbank says that the plant did not at first respond to his efforts, but that after a few seasons it progressed very rapidly. When the experiment was at its height he had several men in the fields every morning during the time of blooming, on the lookout for the slightest variation in the desired direction.

seeds of this plant preserved and sowed by themselves the following season to make the basis of a quite different series of selective experiments.

The history of this new colony duplicated that of other groups of plants undergoing selection. Year by year I found an increasing proportion of flowers with the smoky hue, and always among these a few that revealed the obscure blue pigment a little more clearly.

Finally, after several years of selection, I had a strain in which about one-third of the plants bore flowers of various shades of blue, some smoky or seemingly mixed with black pigment, and others with fairly clear, if not very bright, blue color.

The few flowers that were pure blues were naturally selected to continue the experiment. But their seedlings for the most part failed to reproduce the color.

Selecting year by year, however, among the individuals that produced flowers of the purest blue, the strain was gradually fixed until each year a plot of poppies appeared that, seen from a little distance, presented the aspect of uniform blueness. This, of course, is the patch referred to as exciting the astonished comment of florists that visit my grounds at Santa Rosa about the first of June each season.

On closer inspection of the plot of blue flowers, it will be found that there are still a good many specimens that tend to revert to the more familiar colors. But the effort to establish the blue variety as a fixed type through inbreeding and selection is still under way, and success is assured.

Were the poppy a plant that is propagated by root cuttings or any other of the common modes of division, the blue variety would long since have been given to the world. But as it is necessary with this plant to develop the variety until it will breed true from seed, I have been obliged to continue the experiment at least ten years longer than would otherwise have been necessary.

Now, however, it may fairly be said that the experiment has approached completion. The blue poppy is an accomplished fact. Its production constitutes one of the most striking color modifications hitherto made through artificial selection.

Creation or Reversion?

So far as is known, there was never an ancestor of the Shirley poppy that was blue. So here we have an illustration of an experiment that is radically different from any that we hitherto have had occasion to examine.

We may suppose, to be sure, that the condition of blue pigment is one that occurred in some very remote ancestor of the new poppy. Otherwise we could not account for the presence of the heredi-

A Double Red Shirley Poppy

The general appearance of this flower would scarcely cause one to associate it with the flowers shown in the preceding pictures. But it is only a Shirley poppy modified in yet another direction. Like the other modifications in the form and color of the Shirley, this condition of double petals has been developed by selective breeding along the lines elsewhere clearly explained.

tary factors of blue pigmentation; and obviously it is not to be supposed that our experiment in selection resulted in the creation of new hereditary factors.

But the time at which any ancestor of the poppies bore blue flowers must have been very remote indeed, because no poppy either of the species directly in question or any other species has ever been found anywhere in the world that has a flower of blue color.

So, as just suggested, the bringing out of this color constitutes a development of radically different character from the mere modification of color of a flower within the range of the color scheme of a species, or of allied species, or even of allied genera.

The development of a Shirley poppy that is yellow, for example, which was a second task that a German experimenter set himself, would be comparatively easy, because yellow is a more common color with members of the poppy family, and a tinge of yellow is not unusual.

I have myself developed and introduced strains of Shirley poppies of salmon or deep yellowish pink color. These include various shades of salmon and light scarlet, but with no trace of crimson or of darker colors of any kind.

This flower, which had been selected also for size and crimping of petals and gracefulness, as well as for color, was introduced under the name of "Burbank's Sunset Shades of Shirley Poppies."

But I mention this new variety only to point the contrast. No such amount of work was involved in its production as that which attended the production of the blue poppy, because yellow pigments are in the heredity of the poppies in general, and must have been manifested among the ancestors of any given strain of poppy within relatively recent times.

The affinity between the yellow and red, for example, in the case of the poppy, is clearly enough demonstrated in the experiment, outlined in an earlier chapter, in which I developed a race of crimson California poppies (*Eschscholzia*), the parent species being, as is well-known, bright yellow in color. It will be recalled that the new crimson flower was developed by selection through successive generations from a specimen that showed a little line of crimson, like a streak or thread of another color, lengthwise of a single petal.

California poppies of various other colors were developed in the same way, but there were no blue ones among them.

In the case of these California poppies, then, the relative ease with which the flowers were

A Double White Shirley

One thinks of red as the characteristic poppy color,—particularly if one has seen the poppy growing in an English grain field. But the modified Shirley has been caused to give up its red color, as we have seen; and this picture shows that the white ones, no less than the red, have been induced to produce a multiplicity of petals of greatly modified form and texture. The modification was brought about through selections made in connection with the other lines of improvement of the Shirley poppy.

changed from yellow to crimson would seem to suggest that the latter color lies but slightly submerged, if the expression be permitted, in the hereditary stream, ready to come to the surface if the thin overlaying current of yellow can be removed.

Another illustration of the linking of yellow and crimson in the hereditary scheme of the poppies is given by an experiment in which I crossed two distinct species of poppy, one having flowers of pale yellow, the other pure white.

The hybrids without exception bore flowers of a clear crimson color. There was not a white one nor a yellow one among them.

Another interesting color modification in the case of the poppy was that which produced the so-called silver lining poppy. In this case I discovered a flower in which there was a white line between the black center and the crimson petal. This line was widened by selection until the petal was white with black center, the white extending just over the outer edge of the petal, the rest of the back of the flower being crimson.

It may be interesting to recall in this connection a series of experiments in which the only true California poppy (*Papaver Californica*) was modified by selection, working with a five petaled sport, until a variety was produced that had six petals. The size of the flower was also improved by selection; but the color of the original—a pale orange—refused to budge.

Yet another poppy modification of interest was that through which the Iceland poppy was developed until its seed capsules had fifty-six proliferations instead of the original one.

The Varying Dominance of Colors

The story of the color variation in poppies, as illustrated in the development of the Shirley and its modifications, and in the selective and hybridizing experiments just related, furnishes fairly tangible evidence that the scheme of pigmentation of a flower is of somewhat less fixed or fundamental character than the various characteristics of form and leaf-system and breadth and arrangement of petals and stems and ovules, that are depended upon by the botanist in determining plant relationships.

The fact that a certain flower, for example, may vary in color from bright scarlet to pure white, and from salmon to blue, while still retaining the botanical characteristics that would lead any florist to classify it as a Shirley poppy, in itself demonstrates the comparative unimportance of any particular color in the scheme of plant economy.

There may be special conditions that make a

Contrasting Colors

No phase of flower development has greater interest for the average amateur than that having to do with the modification of color. A bed of Shirley poppies like the ones here shown would give opportunity for an endless variety of experiments in selective breeding. Any amateur may work with the flower.

red flower fit into its environment a little better than a yellow flower, or vice versa; but either red flowers or yellow ones or pink ones or white will attract the insects, and thus fulfill the purpose for which color in the flower has been developed.

That, doubtless, explains why it is relatively easy to modify the color of a flower, within certain limits, and—what amounts to saying the same thing—why the same species of flower may so often be found presenting different colors or shades of color in different localities, or under slightly varying conditions of cultivation. But perhaps the chief interest of the entire matter of the coloration of flowers, and specifically the chief interest of such a development as that of the blue poppy, is found in the suggestions given as to the underlying principles of heredity involved in color transformations.

It would seem as if we are justified in concluding from the evidence that the hereditary factors for the production of many different pigments are mingled in the germ plasm of any given species of flowering plant.

If one color predominates over another in the flower, it is because its pigment is dominant over other pigments, and the study of color dominance furnishes interesting side lights on the question of the hereditary transmission of unit characters.

In the animal world, for example, where the study of the heredity of color has been carried out pretty extensively in recent years, there are interesting combinations showing a somewhat more complex character than any that we have hitherto examined. We have seen that in the case of the guinea pigs black pigment is dominant to white, so that when a black guinea pig is mated with a white one the offspring are black, but the recessive trait of whiteness reappears in one in four of the progeny of the second generation.

But it appears that in these animals, and similar ones that are subject to wide varation of color, there are curious complexities of heredity, all of which, however, so far as studied, fall within the scheme of "Mendelian" transmission.

Thus it is found that in the case of mice, for example, whereas blackness of coat is dominant over whiteness, just as in the case of the guinea pigs' blackness itself may be overlaid, as it were, and entirely obscured by the presence of factors for gray coating, and it further appears that yellow pigment may dominate the gray coat, as well as the black.

A further complication occurs in that an animal that is neither yellow nor gray nor black may be chocolate in color. And it is only in case this color also is absent that the mouse will be white.

Bed of White Mexican Poppies

Mr. Burbank's experiments with the poppies have included a wide range of hybridizing tests, in which species from all over the world were used. Here are some selected white poppies from Mexico that form an interesting colony in one corner of the garden at Santa Rosa.

Moreover, if the factors for chocolate are absent, the factors for grayness and blackness may neutralize each other, and exist in what is called a masked condition, neither one being able to make itself manifest on account of the presence of the other, because both are dominant factors; so that the mouse will be white, yet will carry the factors for grayness and for blackness masked in its germ plasm.

When the chocolate factors are present, however, in addition to the factors for blackness and grayness, the presence of three dominant color factors has the curious effect of enabling one of them, in this case gray, to make itself manifest.

So the chocolate factor is necessary to produce a gray mouse; and the chocolate colored mouse will appear only when the factors for grayness and blackness are absent.

This rivalry of dominant color factors, with subordination of one to another, even though both are dominant over whiteness, has previously been briefly referred to, and it has been noted that, for convenience in describing the condition, biologists have come to speak of a factor that thus subordinates another, in the sense in which gray subordinates black in the coat of the mouse, as *epistatic;* the subordinated color factor (in this case black) being said to be *hypostatic.*

These terms are of obvious convenience, being somewhat parallel in their application to the Mendelian terms dominance and recessiveness, yet being quite distinct, as we have seen, inasmuch as they apply to the relations of factors that are both dominant, yet which refer to the same quality and hence cannot both prevail.

Mixed Factors in the Poppy

Our studies of inheritance of color in the poppies suggest that closely similar relations exist among the pigments of the flowers.

The exact relations of reds and yellows and pinks and blues have not been carefully worked out on a comprehensive scale, as have been the pigment-relations of the coats of mice and rabbits. But the evidence seems to suggest that the relations of red and yellow, for example, in the case of the poppy, are somewhat comparable to the relations of gray and black in the coat of the mouse.

That is to say, both of these are dominant to white, but one of them is epistatic to the other.

It is probable that red is superior in dominance, or epistatic, to yellow, and hence that a poppy will be yellow in color only when the factor for red pigment is either absent or masked.

The experiments that led to the production of the blue poppy suggest the possibility that blue

The Burbank Blue Poppy Contrasted With White Ones

Perhaps the most spectacular of Mr. Burbank's achievements in connection with the modification of the Shirley poppy was the production of a blue variety. Blue is a color so deeply submerged in the heredity of the poppy that it seemed almost impossible to restore it. But by a long series of selections, beginning with a flower that showed a trace of smokiness, Mr. Burbank finally produced the variety here shown,—a flower having rare distinction.

pigment may occupy some such place in the scheme of coloration of the poppy as that occupied by the chocolate color in the scheme of the mouse's coat. In that case, a poppy would be blue only in case the color factors for red and yellow were both absent. And a poppy would be white only in case the color factor for blue was absent, although there might be present color factors for both yellow and red in the condition of equilibrium which we have spoken of as masked. A dingy white flower might contain a trace of blue.

This supposition might explain the case of the yellow poppies crossed with the white ones, in which the hybrid offspring were all crimson in color. The hybridizing in this case may be supposed to have brought together latent or masked factors for red (present in the white flower), the mating of which gave that color dominance, and enabled it to assert itself, while the yellow factors were unable to assert themselves, yellow being hypostatic to red.

Suppose, for example, that the yellow poppy bore factors for yellow and blue; and the white one, factors for red and yellow. The combination would bring together red, plus yellow, plus blue; and red would be manifest, the other colors being masked. Re-combinations should be expected in the next generation.

But the actual conditions are probably a little more complex even than here suggested. The smoky character of the blue poppies, especially in their earlier forms, seemed to suggest the presence of a factor for blackness. And, indeed, the fact that black pigment constantly tends to appear in the poppies shows how potent an influence this is. So, when the entire hereditary color scheme of the poppies is untangled, it will probably be found that there are dominant factors for red and yellow and black and blue corresponding more or less to the yellow and gray and black and chocolate pigments of the coat of the mouse; and that these are mutually dependent on one another in an intricate fashion, the full explication of which would give us a far clearer comprehension of the mysteries of the color transformation in the poppy and in other flowers than anyone can claim to have at present.

It is because of the new light they throw on this problem that experiments that led to the production of a blue poppy seem to have unusual interest and importance. But long series of additional experiments involving much expense and many discouragements will be necessary before the exact relations of the different pigments in the poppy, or in any other flower, will be fully understood.

Shasta Daisy and One of Its Parents

The Shasta daisy is a new species developed by Mr. Burbank through the combination of the strains of a European daisy, an American daisy, and a Japanese daisy. A typical Shasta daisy is here shown, together with a specimen of the American ox-eye daisy, one of its progenitors.

A Daisy Which Rivals The Chrysanthemum

And Other Improvements in Daisies

THE story of the origin of the Shasta daisy was told in an earlier volume.

It will be recalled that this new flower, differing so widely in size and form and appearance from any daisy hitherto known, is in effect a new species produced by the combination of three species (and a fourth variety) that came respectively from Europe, from the eastern United States, and from Japan.

The long series of experiments through which the European and American species were first hybridized, and the Japanese species subsequently brought into the combination, followed by new crossings and selections season after season through a long term of years, has been told in detail. Here it seems desirable to refer to more recent modifications of the Shasta, giving some specific hints as to its cultivation, and to review the work done with certain other daisy-like plants —to which also reference was made in an earlier volume—with particular reference to the interpretation of the results accomplished, in the light of the new information supplied us by observation of other series of experiments.

First a few words as to the progress of the Shasta daisy, which, as we have learned, not only constitutes virtually a new species, but has given rise to a great variety of modified forms, all of them Shasta daisies, yet differing as markedly among themselves (in form at least) as, for example, different races of roses or poppies or dahlias differ.

The racial strains of the three original parent species have been so recompounded, and, as regards their broader outlines, so truly fixed in the new species, that no one who sees a Shasta daisy can fail to recognize it as a Shasta—just as we recognize a rose or a poppy or a dahlia — even though the particular specimen under observation differs very radically as to size and form and arrangement of petals from anyone of the half dozen varieties that may be under observation at the same time.

And the meaning of all this has been made clear to us in our studies of other forms. The separation of unit characters through hybridizing

Graceful of Flower and Stem

In developing the remarkable Shasta daisy, Mr. Burbank did not confine himself to observation of any single character, but took into consideration at all times not only the flower itself, but also the stem and the manner of growth. Through rigid selection, in connection with the hybridizing experiments, he produced a flower that is peculiarly graceful both as to blossom and as to form and manner of growth of stem.

different species, and the recombining of these characters in the offspring of the second generation and subsequent generations, which is so vividly illustrated in the case of the Shasta, has been illustrated also in scores of other cases, until the principle involved has become so clear and obvious that no one is likely to overlook it.

So, as I said, it is not necessary here to recapitulate the details of the series of hybridizing experiments through which the Shasta daisy was evolved. We shall be concerned with a few practical details as to the cultivation of a plant which is making its way into gardens everywhere, and which is sure to increase in popularity as the years go by.

Spread of the Shasta

Probably no flower ever introduced has been more thoroughly appreciated and more rapidly and widely disseminated than the Shasta daisy. Owing to its hardiness, it can be grown anywhere from Alaska to Patagonia, and it requires almost no attention, except a biennial division of the clumps into numerous small plants, each piece of which will soon make a vigorous new clump.

It is now widely grown throughout both temperate zones, and is rapidly becoming popular as a park and garden plant. It is greatly in demand for interior decorations, partly because its cut blossoms will last fully two weeks, whereas those of dahlias, roses, and lilies usually become quite unsightly after two or three days.

Under no circumstances should the Shasta daisy be grown from seed, unless it be for the purpose of producing new varieties. No one would raise Chinese or Japanese chrysanthemums, roses, or carnations from seed, and hope to obtain the beautiful forms and colors peculiar to the selected plants. Strains produced by hybridizing vary more or less; upon this, of course, depends their chief value to the gardener who wishes to produce new varieties; but from the very fact of their mixed heritage these plants will not breed true from seed.

But they are readily propagated in any desired quantity from the root of the mother plant.

Reference has been made to the double forms that have appeared among the seedlings. Some of these bloom so freely as to destroy the vitality of the plants, unless some of the buds are removed. Other varieties have appeared with long, slender, lacinate rays, giving the blossoms a soft, feathery appearance; others still with curious twisted ray-flowers, or with long, tubular, or drooping ones, or those that are curled inward and upward, producing beautiful, cup-shaped blossoms; and all these in double form like roses, carnations or dahlias.

A Bed of Shasta Daisies

As an ornamental plant to be grown in masses, the Shasta daisy has few rivals. It is extremely hardy, in addition to all its other good qualities, and it spreads by root division, so that a single plant presently supplies material for a large bed.

All these curious forms can be reproduced indefinitely by division, but not one time in ten thousand can the best ones as yet be reproduced from seed.

Practical Hints as to Culture

The Shasta daisy, though an exceptionally hardy plant, is, to a certain extent, sensitive to the conditions of its environment, and in order to secure the most thrifty plants and the most attractive blossoms it is necessary to follow certain rather definite rules of culture. The best results follow a division of the plants about every third year. If it is desired to develop strong, vigorous plants from the start, the old plants should not be allowed to bloom, else the cuttings taken from them will possess but scant reserve vitality.

The plants should be divided into pieces as small as possible, care being taken to leave a bud and a few leaves and roots attached to the cutting, though the roots may be omitted, provided the shoots are properly treated. The long slender leaves should be cut back about one-half their length, so that they do not take too much moisture before the roots develop. After rinsing the cuttings in cold water they should be closely planted in a bed of sifted sand, indoors or out, according to climatic conditions.

In order to settle the soil around the cuttings, they should be drenched with water, and a uniformly moderate supply of moisture should be maintained.

If these instructions are followed, even the smallest, most unpromising cutting may develop into superior plants. When the slips are strongly rooted, they should be placed in a sunny place in rows eighteen inches to two feet one way by three or four feet the other. They should be thoroughly watered and treated like other garden plants. During July, August, and September each of the original cuttings should bear from twenty-five to fifty large, beautiful white blossoms. During the second season the best varieties should produce from one hundred to two hundred blossoms, measuring ordinarily from three to six inches in diameter.

For the production of new varieties, Shasta daisy seed may be sown thickly in boxes of sandy soil or in out-of-door beds in California. If the seeds are those from the improved varieties, the resulting seedlings will bloom the first season, although the older varieties did not bloom till the second season, and then not as abundantly as these do the first. But the seedlings will form a motley company, many of them reverting to ancestral forms and departing widely from the characteristics that have made the fame of the Shasta daisy.

A Freak Daisy

The tendency to variation induced in the progenitors of the Shasta daisy through hybridization, is manifested in a great variety of ways. Here is a specimen in which the ray flowers are multiplied in number, and some of them curiously altered in form. Such a specimen as this might become the progenitor of an altogether double Shasta, the ray flowers gradually supplanting the seed-bearing organs at the center of the flower.

But might we not by careful selection fix the Shasta as a form that would breed true from the seed?

Could the Shasta Be Fixed?

The question is one that is not without practical interest. For there is obvious convenience in being able to grow an ornamental plant from the seed, even though it be possible to propagate it indefinitely by division. A small package of seeds may be shipped far more readily than roots or entire plants, and no doubt a large number of people will grow a plant from the seed who will not take the trouble to transplant roots or work from cuttings.

So, as I say, the question as to the possibility of fixing the Shasta is not without practical importance. But the question also has a theoretical interest in connection with the general problems of the plant developer as applied not merely to this species but to many others.

Our studies of many forms of plant life have taught us that the cultivated varieties of flowers, and of fruits and of vegetables as well, are so complex as to their heredities that—except in the case of certain annuals—they do not breed true from the seed, and are not habitually propagated in that way. Yet, on the other hand, we have seen that it is possible to fix new races by careful selection, and the principles according to which the experimenter works in effecting such fixation have been pointed out again and again.

Making application of the knowledge thus gained to the case of the Shasta daisy, we need have no hesitancy in asserting that it would be possible to fix races of this plant so that they would reproduce their type with approximately the certainty from the seed as do, for example, the original parent forms from which they spring. But this task is as unnecessary as would be the task of fixing roses, carnations, or chrysanthemums.

If inquiry is made as to the length of time required to effect such fixation of type, the answer can be given with a fair degree of certainty. Working along usual lines, by selecting the best specimens in a large company and in the successive year the best specimens among their progeny—extending, in other words, the method of selection through which the new races were originated—it would probably require from six to ten generations of selection to make sure of securing a specimen from the germ plasm of which disturbing hereditary factors had been eliminated by selection so that the factors that remain are those that produce the qualities that we desire to retain.

But if it were feasible to devote the space and

Bouquet of Fluted Shastas

Sometimes one may find among wild ox-eye daisies a specimen that has a tendency to fluting of the ray flowers. In some of the improved Shastas, this tendency has been accentuated and exaggerated, as here shown. This variety of Shasta bears a close general resemblance to its cousin, the chrysanthemum.

time to an experiment of a somewhat modified character, it would be possible, in all probability, to fix the type of any given race of Shasta daisies in a single generation and, after another generation to test the result, to secure seed that would reproduce plants duplicating the parent form as closely as offspring ever duplicate their parents.

The practical manner of working through which this more rapid fixation of type would be effected would consist in selecting among a large company of seedlings grown from seed of a single typical plant the individuals that represent the parent form most closely. There are sure to be some of these among the thousands. These, indeed, are the ones that would be selected in any event by the experimenter who was planning to fix a type.

Let the seed of each individual plant of these type specimens be sown in a separate plot; and in due course isolate each seedling so that each individual plant is self-fertilized. We shall then find that among the offspring of each plant there is the utmost diversity, but it will appear, in the next generation, that there are some plants that breed true to type and others precisely similar in appearance that produce diversified offspring. In other words, the practical method of isolating each individual through two generations would enable us to determine which ones have in their germ plasm only the factors that we desire to see perpetuated and which others have the mixed factors that we wish to see eliminated.

The suggested manner of selecting by isolation of individuals merely enables us to go more directly to the goal. It does not differ in principle from the ordinary method of selection. Eut the isolation of each individual, so that its traits may be separately tested, enables us to reach the result in two years, instead of requiring perhaps from six to ten years.

It will be recalled that it was through the application of this method that Prof. Biffen was enabled to isolate and fix his new race of wheat that is immune to rust in the third generation. But it must be recalled that Prof. Biffen was working with only a few hereditary factors or characteristics and that he was also working with a plant that is self-fertilized.

To follow out the principle in the case of a plant like the Shasta daisy, in which a large number of hereditary factors are under consideration, would involve the handling of very much larger numbers of seedlings. And the fact that these must be isolated not merely in location but must also be guarded against cross-fertilization introduces a further complication.

So it will be only an experimenter with plenty of time on his hands who could undertake to fix the type of the Shasta daisy by this rapid method. The experimenter who has numberless other plants to consider at the same time would be obliged to content himself with the older method, selecting, generation after generation, the individuals that came truest to type, and preserving their seed only from which to grow seedlings for another selection next season. But this method, while lacking the precision of the other, has served admirably well in a multitude of cases, some of which we have seen illustrated in recent chapters.

So the experimenter who wishes to fix a race of Shasta daisies may with confidence go about the work along precisely the same lines that were used, for example, in the production of the wild *heuchera* with crinkled leaves—the method, for that matter, through which the races of Shastas were themselves developed after hybridization had supplied the material for selection.

Colored Daisies

It will be recalled that final hybridization through which the Shasta daisy was produced was made chiefly with an eye to the removal of the last tinge of duskiness and a greenish yellow shade that is more or less present in all white flowers, leaving a flower of snowy whiteness.

Semi-Double Shastas

Here are some Shastas in which the tendency to increase of ray flowers shown in an earlier picture has been accentuated through selection, until comparatively little of the central seedbearing portion of the flower remains. Contrast this flower with the little ox-eye, as showing vividly the changes that may be wrought in a flower in the course of a few generations of selective breeding.

It will be understood, also, that this quality of whiteness characterizes all the new races of Shastas—except one that has been bred for yellowness. The number of florets and their arrangement and form and size have been modified indefinitely, but these modifications do not in any way affect the color, except in case of one that showed a tendency toward yellow, and from this numerous yellow varieties, single and double, were developed. This color, however, fades in sunlight, and blanches in a few days. Aside from this, all Shasta daisies are characterized by their snowy whiteness. The improved varieties rival the variously modified chrysanthemums in size and form and in flexibility of florets; but they do not imitate the chrysanthemums as to variety of color.

Possibly some varieties of Shasta may be modified in other directions as to color. One already shows pink on the outside of the ray flowers. One was found last year (1913) that had a faint shade of pink, and seed was saved. A pink Shasta daisy is therefore in prospect.

There are other varieties of daisies, however, that show color variation. The whiteness of the ox-eye daisies both of Europe and America, and of the French marguerites, seems so typical that at first thought it appears anomalous that any daisy should depart from the traditional color.

But, on the other hand, our studies of flowers have shown us that color is the least fixed characteristic of the floral envelope, and, reasoning from analogy, it would be rather surprising if there were not races of daisies, more or less closely related to the parents of the Shasta, that have colored blossoms.

In point of fact, the Paris daisy has one lemon yellow variety; and there is a so-called daisy indigenous to South Africa, but for a good while cultivated in Europe, that has blossoms of a rather brilliant orange. This so-called African daisy, however, is not very closely related to the true daisies. The reader will recall a chapter of the first volume in which the story of this flower is told. It will be recalled that there is a closely allied species of daisy from the same region of South Africa that differs from the orange one chiefly in the fact that it is pure white.

It will further be recalled that when these two species, the orange and the white, have been hybridized in Europe, the hybrid offspring shows an astonishing diversity of color.

Not only oranges and yellows of many shades, but shades of purple and red also appear. It was by selection among the red hybrids, as will be recalled, that a so-called African daisy of a beautiful and uniform pink color was developed.

A Bouquet of Double Shastas

In this variety of selected Shasta, the "petals" have been greatly multiplied, and the inner ones have taken on a fimbriated character that is peculiarly attractive. The flowers have not quite given up the habit of seed-production, however; so further development is possible in the course of successive generations.

It will further be recalled that among the hybrids were some which showed, on the backs of their petals, streaks of purple, showing that factors for blue color, as well as factors for yellow and red, are present.

The interest of this experiment, as a mere illustration of a new race developed by hybridization, is not inconsiderable. But the chief interest of the experiment centers about the production of new colors which appeared to be alien to the hereditary traditions of the African tribe.

Properly interpreted, the facts brought to light by these experiments fall in line with a large number of observations having to do with the colors of flowers, and give intimations of an interpretation of the entire subject of floral coloration.

In attempting to interpret the facts, we should bear in mind what was learned in the preceding chapter as to the variable coloration of the poppies, and we shall have occasion to draw other illustrations from plants of a good many different types. We have found reason to believe that most flowers owe their color to a mingling of pigments, or at all events have in their hereditary strains the factors for many different colors, somewhat as even the purest tones on the canvas of the painter are usually the result of the blending of diverse pigments.

We shall find reason to believe that even the white flower is not as a rule white because it lacks the factors for color pigmentation, but because it mingles these factors in such a way that they mutually antagonize, or neutralize, or "mask" one another.

In this view, then, the production of a pink African daisy through the hybridizing of an orange and a white one may be regarded not as an anomalous phenomenon but as a typical one—albeit the experiment has a good measure of interest none the less.

Variation of Color in Flowers

The fact of color variation in the flowers is, as just stated, too obvious to escape notice of the least observant. A good many people, however, are unaware of the wide range of variation shown among wild species.

It is sometimes assumed that color variation is due to the cultivation of plants; and, of course it is true that cultivation has resulted in developing races of flowers of diversified colors. But it is not to be supposed that these colors could have been developed in the short period during which the plants have been under cultivation had not the materials for color variation been present in the various hereditary strains.

And it requires but the briefest search among

Bouquet of Freak Daisies

We have learned through observation of many examples that when a flower or plant once begins to vary, it may continue to vary almost indefinitely. Here is an illustration of a new departure on the part of the Shasta daisy, in which the "petals" take on a very curious form. It has interest as a freak rather than because of its beauty, but the variety is worthy of further attention, to see what may be its limits of variation in this direction.

wild flowers to show that color variation is by no means exceptional, but is, on the other hand, quite the rule here, even as among cultivated species. With a wild species, to be sure, there is usually preponderance of one color or another, because natural selection tends constantly to fix or accentuate one character and to minimize or eliminate another. In some respects the guide marks on the flower seem as important as the color itself.

But that even under natural conditions it may not make a vast difference to the plant whether its advertising floral envelope, to attract the attention of insects, is of one color or another, is suggested by the frequency with which we find plants of the same species putting forth flowers widely different in hue.

Let me cite a few instances, taken quite at random. They will suggest the extent to which one color may do service for another in the same species; suggesting also the probability that hereditary factors for all the colors manifested by different specimens of a species are well represented, at least in a latent condition, in the germ plasm of all specimens of the species.

The nemophila, a common wild plant in California, has flowers that are generally clear, pure, skyblue, but this varies in different localities through all shades to snow white. Pink varieties are occasionally seen. Sometimes also the blue flowers are edged with white; and on occasion one sees white flowers with a blue edging, and sometimes a shade of yellow.

The coast tree lupine, another wild plant, bears spikes of brilliant yellow flowers. But these may vary from lemon yellow to sulphur yellow, brownish yellow, smoky yellow, redish, pale blue, yellowish blue, dark blue, and pure white. Bright yellow is the typical or usual color, and white is quite rare. The other colors are not unusual.

The *Limnanthus douglasii* is a wild swamp plant the flowers of which sometimes seem to carpet the ground. The upright, bell-shaped flowers are usually milk white. But I have received specimens from the Sierras that were yellow.

The beard-tongue, a relative of digitalis, of the species known as *Pentstemon barbatus,* has flowers that vary from scarlet to almost pure yellow and white.

The crimson clarkia and the bluebell have flowers the colors of which are indicated by their respective names; but both on occasion produce blossoms that are pure white. Everyone knows that the heliotrope, the lilac, and the violet, among cultivated flowers, are often represented by white forms—and the violet by other colors. The same is true of the whitelaria, the typical flowers of

Clusters of Pentstemons

The pentstemons are exceedingly hardy and thrifty flowers of which there are many native species, as well as a good many foreign ones. There is a wide range of form and color so that the flower is a particularly attractive one for the experiments of the plant developer.

which are also blue, and of the trailing myrtle, the characteristic blue flowers of which are sometimes modified to crimson and to white.

The gillias may show in the same patch flowers of the deepest crimson, others that are pale rosy crimson, yet others that are pink, and numerous ones that are pure white.

These examples of variation in different flowers of the same species may be supplemented by mention of the curious flower known as cynoglossum, of the borage family, the flowers of which are blue in color until they are fertilized, then becoming deep red. Somewhat similar are the color changes of one of my new varieties of poppy, which vary from day to day. And this phenomenon of changing color while still retaining freshness may be linked with the observation that nearly all flowers change in color after they pass maturity, losing their brilliancy as they wither, and ultimately taking on altogether modified hues.

With these illustrative cases of the varied coloration of flowers in mind—and of course the list might be extended indefinitely—it no longer seems strange that our orange and white African daisies have the potentialities of a pink daisy in their hereditary strains. There is every reason to suppose that the two African daisies are descended from the same original form. It is probable that the existing differences in their colors are due to somewhat recent modifications.

Possibly the orange African daisy grew in the open, where it was subjected to the influence of sunlight; and the white daisy in a woodland or marsh where it was much in the shadow.

It is a general observation that shade loving plants, like those that open their flowers in the twilight or at night, tend to produce white flowers or at most those dressed in light and pale colors; whereas the blues and oranges and reds are worn principally by flowers that grow in the open and put forth their advertisement for insects in the sunlight.

So we may reasonably suppose that the white African daisy owes its present color to the influence of natural selection, and that it had among its ancestors plants that bore colored flowers. In any event, the orange African daisy has pigments of its own, without invoking the aid of ancestors, and their orange color shows that there are elements of red mixed with the yellow. These elements, sorted out through hybridization, sufficiently account for the pink progeny.

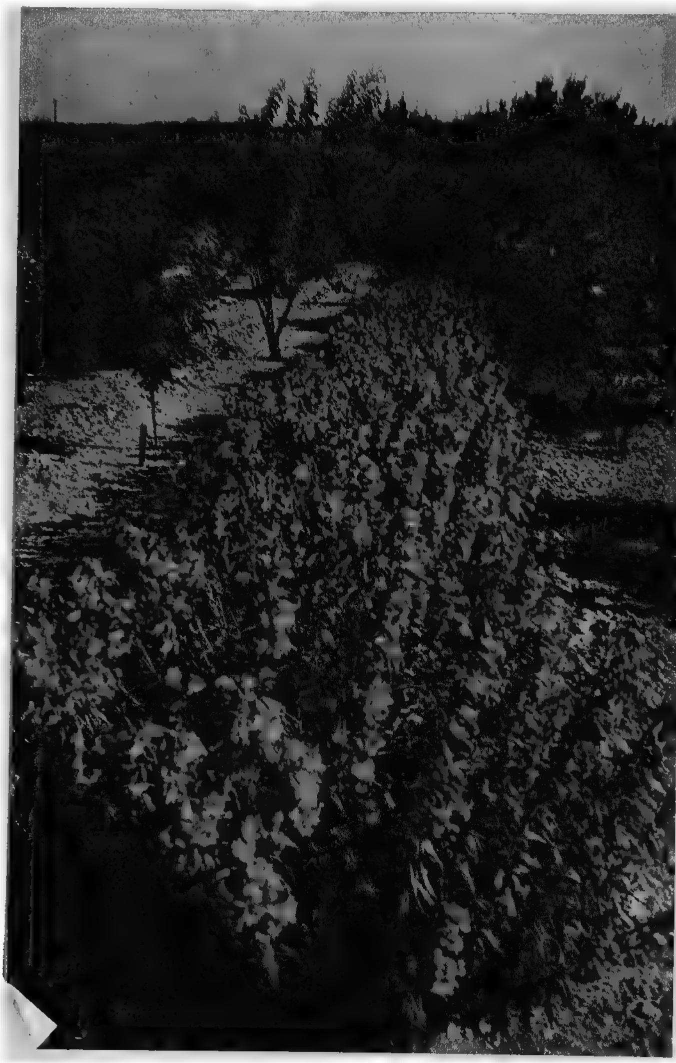
But among the hybrids of the yellow and white African daisies, in addition to the pink ones, are numbers that are yellow; and, in about equal proportion, others that are white. These white individuals closely resemble their white parent; yet, as one of their parents was the orange daisy, it is obvious that they have in their germ plasm factors for yellow pigment, even though these are not revealed.

These hybrids, notwithstanding the strain of yellow in their germ plasm, are as white to all outward appearance as their white parent; a fact which, taken by itself, sufficiently demonstrates that the white parent itself may have the submerged factors for pigment in its germ plasm.

In point of fact, it appears to be sufficiently established that white flowers may be white not because they altogether lack hereditary factors for pigmentation, but for the paradoxical reason that they possess these factors in superabundance.

We saw in our discussion of the colors of the poppy that there is reason to believe that two dominant colors, grouped together, may neutralize or mask each other and produce no tangible character.

If we revert to an illustration used in another connection, in which we imagined that elfin architects are at work in the germinal nucleus, matching up the different hereditary factors to build a new organism, we may suppose that occasions arise when there is a superabundance of material (in the case under consideration, let us say, ma-



A Bed of Pentstemons

Of course Mr. Burbank has experimented extensively with the pentstemons. Here is a sample bed of these flowers in one of his gardens. Note the attractiveness of this selected variety as a border plant.

terials for both yellow blossoms and red blossoms), and that in such a case the architects might agree on a compromise in which neither yellow nor red pigment is used, the flower being allowed to remain white.

We saw evidence that there are such latent color factors in flowers in such a case as that of the yellow poppy that when matched with a white one produced a galaxy of crimson poppies. The case of our orange African daisy mated with a white one is a variant on the same theme.

And the illustration just cited of the different cases in which flowers of the same species have blossoms that may run the gamut of colors from scarlet through yellow to blue, or may lack pigment altogether, shows how common is the phenomenon of the mixture of factors for different colors in the same germ plasm.

We shall perhaps not be far wrong if we assume that every colored flower has underlying potentialities of other colors than the one represented. And there is a good deal of evidence to suggest that yellow underlies red and is dominated by it when there is a mixture of different factors; that blue, lying toward the other end of the prismatic scale, stands rather by itself and in a way opposed to the other colors; and that white, as just suggested, may represent either the absence of factors for pigmentation or the presence of two or more conflicting pigments that neutralize each other.

In another connection we shall discuss a theory as to the way in which the various colors, as utilized by the flowers, were introduced, and the significance of their various blendings.

—We shall find reason to believe that even the white flower is not, as a rule, white because it lacks the factors for color pigmentation, but because it mingles these factors in such a way that they mutually antagonize, or neutralize, or mask one another.

A Contrast in Gladioli

Mr. Burbank has devoted an exceptional amount of time to the development of the gladiolus, and the results attained have been very striking. He has used many varieties in crossbreeding experiments. This picture shows a contrast between one of the original varieties and a cluster of its improved descendants.

Making The Gladiolus Surpass Itself

Teaching The Plant New Habits

THE history of the growth of ideas shows some curious paradoxes. As a minor illustration in point, it may be recalled that an English clergyman was doing his best—and a very good best it was—to build up evidence of the mutability of natural species at a time when it was rankest heresy to suggest that species are mutable.

The clergyman in question was the Honorable and Reverend Dr. William Herbert, Dean of Manchester. His work was carried out in the early decades of the nineteenth century. He was a horticulturist of great skill, and he labored assiduously with many plants. And among those with which he attained conspicuous and striking results that seemed to belie the botanical beliefs of the period, was the plant now familiar in every garden as the Gladiolus.

The time when the important work of this clerical amateur was carried out was one in which such men as Erasmus Darwin, the poet Goethe, and the French biologist Lamarck were advocating the idea of the mutability of species. And no doubt the Rev. Herbert had some of their theories in mind as he went about his plant experiments in the gardens of the Manchester Deanery.

Yet in the main he was probably quite unconscious of the full significance of the experiments that he was performing.

The particular experiments that are of interest to us in the present connection are those in which he hybridized one species of Gladiolus with another, and in so doing not only produced new races of gladiolus, but proved to his own satisfaction that these new races were altogether fertile.

Almost half a century later Charles Darwin in his "Origin of Species" had occasion to quote the opinion of the Rev. Herbert, based on his experiences with this flower and several others, to the effect that hybrids are not necessarily sterile—a point that was still ardently in debate. He even cites Herbert as having claimed that the hybrids gained in fertility over the original species—a fact which Herbert himself regarded as being "a strange truth", but regarding which Darwin, writing with fuller knowledge, asserts that it was by no means so strange as it would appear.

A European Hybrid Gladiolus

For many years European horticulturists have experimented with the various gladioli, hybridizing them extensively. Here is one of the European hybrids, which has been used by Mr. Burbank in further breeding experiments.

To be sure, nothing revolutionary came directly from the reverend horticulturist's experiments. He produced interesting new varieties of flowers, but the theoretical bearings of his work were doubtless quite ignored by his fellow clergymen, and, indeed, as I have already suggested, were probably only vaguely realized by himself.

Yet as we look back on this work now, from the new point of vantage that Darwin gave us, we can see that the work of this amateur horticulturist must have had its share in disturbing the ideas of at least some of the persons to whose attention it came, and in preparing the way for the new view of the flexibility of species that now seems so much a matter of course that we can hardly realize how revolutionary it seemed to our forebears of two generations ago.

A demonstration made with a plant that grows in everybody's garden, has force that comes home to us more cogently than records of any number of observations of animals and plants of tropical forests and South Sea archipelagoes. And a number of new species of plants, gladioli among others, that the Dean of Manchester created by hybridizing old ones made their way into the gardens of Europe, and gave their message, we may be sure, here and there to a receptive mind in substantiation of the disputed evolutionary doctrine, which,

An Improved Gladiolus

In Mr. Burbank's experiments with the development of the gladiolus many points were to be considered, as is the case with most flowers. Here are specimens that show the result of efforts to broaden the petals, and give them firmness of texture.

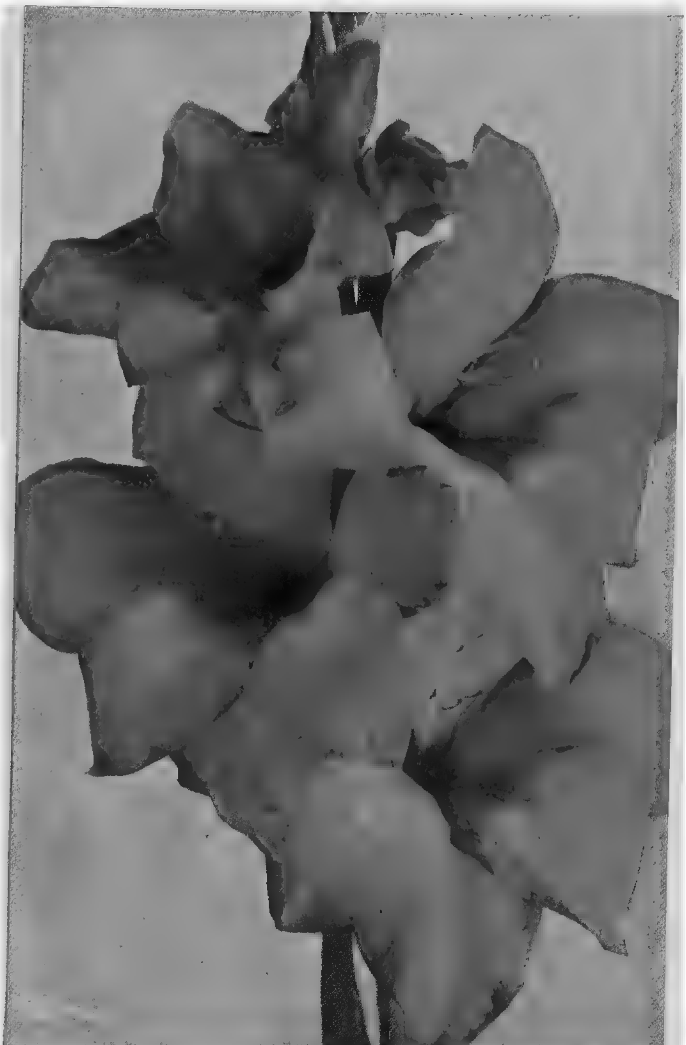
even before the publication of Darwin's "Origin of Species", was exciting the interest of the thoughtful.

Other Gladiolus Hybrids

Before the gladiolus made its full conquest of the popular gardens, however, it was further improved by other gardeners, both in England and in continental Europe.

The species that the Rev. Herbert had crossed were the showy *Gladiolus cardinalis* and the smaller but more free-flowering *Gladiolus blandus*. Subsequently he crossed a number of other species, and produced races of great beauty and fertility. But a race produced by Mr. Colville at Chelsea in 1823, by fertilizing the form known as *Gladiolus cristis* with the pollen of *Gladiolus cardinalis* gained additional popularity.

It was not until 1837, however, that the form was originated which was to make actual conquest of gardens throughout Europe, and presently to attain corresponding popularity even in America. This new form which became the parent from which most modern varieties of gladiolus have been developed was raised in 1839 by M. Bodinghaus, gardener to the duc d'Arenburg of Enghein. Like the other hybridizers, he used *Gladiolus cardinalis* for one parent form, the other parent being a species known as *Gladiolus psittacinus*.



Increased Size and Compact Growth

Another quality sought by Mr. Burbank in the development of the gladiolus was the habit of compact growth on the stem, so that the flowers should be solidly massed, instead of being scattered along the stem. This specimen shows striking success in this regard, as well as in the increased size and symmetrical form of the flowers themselves.

We have seen that the cardinalis was used by the earlier hybridizers. It appears that the psittacimus was also used in hybridizing experiments by the Dean of Manchester. But either he did not make the precise cross that was now made by the Belgian gardener, or the strains he used were somewhat variant; for the hybrid now produced had qualities that gave it a new appeal to flower lovers in general, and in particular made it a flower of such easy cultivation and such striking appearance as to make a strong bid for popularity among amateurs.

It gained such vogue as to be thought of everywhere not only as a distinct species but as representing a type form of the race of gladioli. It was named Gandavensis, from Gand (Ghent), the place of its origin.

It is believed, however, that the form of gladiolus that came to be known everywhere as the Gandavensis has in its racial strains the blood of many other species beside the original parents. It is almost certain, for example, that the strain of *G. oppositiflorus* accounts for the modifications of form and for the introduction of a tendency to produce white flowers; and that strains of *G. blandus* and *G. ramosus* have also been introduced.

In a word, the form of gladiolus that came to be familiar everywhere under the name Gandavensis is not merely a hybrid, but a hybrid that probably carries the racial strains of at least four or five species, and possibly of a good many more than that.

All of which is essential to an understanding of the later developments of the race of gladioli.

For when we come to investigate the pedigrees of the chief races of gladiolus that are now found in our gardens, we learn that, practically without exception, they are hybrids that carry the Gandavensis strain among others, and hence are multiple hybrids, the precise lineage of which is too intricate for tracing.

It is this fact that accounts for the wide range of variation as to form and color that characterizes the gladioli of our gardens. For the hybrid races have practically supplanted the original species everywhere.

The same thing is of course largely true of most other cultivated flowers, and it is altogether true of the cultivated fruits and vegetables. As regards a large proportion of these, the cultivated varieties have not only supplanted the original species but no definite record remains of the original species themselves. The case of the gladiolus differs, and gains added interest, in that the original species were brought from Southern Africa to Europe only a little more than a century ago. The develop-

Bed of Experimental Gladioli

Here are gladioli of the same fraternity, but showing a wide range of variation. Only two or three of the best, out of the large number in this colony, will be selected to continue the experiments.

ment of the new hybrid races under cultivation, and the elimination of the parent forms by their improved descendants, has taken place in so comparatively short a time that its chief steps are matter of record, as we have seen.

So the story of the gladiolus has elements of educational interest for the plant developer that are quite lacking in many of the cultivated plants which attained relative perfection at an earlier period.

Early Work At Santa Rosa

There are a few species of gladiolus that are native to Europe and Asia, but the ones that were chiefly used by the early hybridizers came from South Africa, as already related.

Doubtless this fact was not without significance in determining the results of the work of the early cultivators. We have seen illustrated more than once the effect of transplanting a plant to new soils, and in particular of transporting it from one hemisphere to the other.

We cannot doubt, then, that the change in the seasons and in the soils and climatic conditions in general had a share in promoting the variability of the gladiolus when brought to Europe, although, as we have seen, the tangible stimulus to variation was given through the now familiar method of hybridization.

And, by the same token, we may suppose that when the gladiolus was finally brought to California, shifted thus half way 'round the globe from its new home in Europe, there was an added stimulus given, urging the plant to still further modifications of habit, and supplying yet other elements of variation with which the plant developer might work.

At all events the gladioli in my gardens at Santa Rosa and Sebastopol have proved responsive and adaptable. And further modifications have been produced in the much modified flower that add greatly to the value of what was from the outset one of the most popular of ornamental plants.

I began work with the gladiolus about the year 1882, starting with the Gandavensis hybrid, the origin of which has already been described.

At that time there was no great interest taken in America in growing gladiolus seedlings, but I was able to secure a large number of the best types of Gandavensis, and also obtained bulbs of about a dozen of the natural species.

I obtained my material not alone from American growers and the cultivators of Europe, but also directly from South Africa.

I began from the outset to experiment on a comprehensive scale, raising the gladioli by the half acre and acre on my Sebastopol place. The

A Graceful Variant

The gladioli of this cluster have departed rather strikingly from the traditions of their tribe, as to arrangement of the flowers along the stem. But there is something strikingly attractive about the manner of clustering adopted by this variety, and we may feel sure that this specimen will be among those selected and allowed to go to seed, in the interests of future generations.

first fault observed in the seedling gladiolus was that the blooms would not stand our California sunshine.

Under the glare of the California sun, the blooms would wither in a single day, sometimes in a single hour.

Other serious defects were that the stalks were too slender, and the flowers too far apart on the stalk. Moreover, the flowers were small, they were illy arranged on the stalks, giving an untidy appearance to the plants; and often they were only half open when at their best.

The colors of many varieties, on the other hand, were fine, it being evident that selection had been made largely for color, by some at least of the earlier experimenters. My first object, then, was to remedy the defects just mentioned rather than to modify the color of the gladioli. In particular I sought, while improving the stalks and the arrangement of flowers on the stalks, to make the petals of the individual blossoms stand out flat and in regular sequence.

The work progressed along the lines of hybridizing and selection with which the reader is already familiar. I hybridized freely, introducing strains of the long neglected natural species to give added virility and stimulate still further variation, thus providing materials for selection.

Growing the plants by the acre, I had abundant material for choice, and my usual method of choosing only a few of the very best representatives of the different forms that seemed worth developing, destroying the rest, was rigidly exercised.

I succeeded so well that in the course of a few years there developed varieties which were introduced with new names, and which made their way everywhere, and were highly prized by gardeners throughout the United States.

Doubtless the most interesting development in this early period was the form named the California. This was a really magnificent semi-double variety which not only excelled in the form and size and color of the individual blossoms, but which had the added peculiarity of bearing the blossoms all around the stalk like a hyacinth, instead of merely on one side of the stalk as had been customary with all other varieties of gladiolus.

Even at the present time, although the varieties of gladiolus have been subject to rapid development within the past few years, I recall the California as one of the most beautiful flowers of the family.

Unfortunately this plant was lost, probably by freezing, along with the entire stock of other gladioli, by an eastern dealer to whom it was sold.

Color Variation in Seedling Gladioli

Few Plants offer better opportunities than the gladioli for studies of color variation. The original wild species differ widely in this regard, and their crossbred descendants naturally show striking combinations of colors. Plants grown from a single lot of seeds may show such variation in flower coloration as is here depicted.

My gladiolus colony progressed admirably, and the new forms attained a degree of virility that made it no more difficult to raise them than to raise potatoes; indeed, much less difficult, inasmuch as the gladiolus bulbs in California do not require to be dug or stored, but continue their growth throughout the year. The only object in digging them is to divide and separate them for multiplication.

The forms of the plants, and the manner of bearing, as well as the shape and arrangement of the blossoms, improved year by year, and the new varieties of gladiolus came to be well-known to dealers throughout the country, and were still under process of development when an unexpected complication put an end, for the time being, to my further work with this plant.

War With The Gopher

The complication manifested itself in the discovery that entire rows of the gladiolus bulbs had been eaten by pocket-gophers, which had tunnelled their way into the grounds, and, boring beneath the gladiolus beds, had feasted on the bulbs, destroying large numbers of them (mostly during the dormant season) before I discovered the presence of the marauders.

The plants do not wither at once even when the bulbs are greatly injured, or in the dormant season totally destroyed. So long rows were destroyed before I knew the necessity of combating the enemy.

The attempts to exterminate the pests were at first so unsuccessful that I presently decided to give up the gladiolus colony altogether. I sold the entire lot to an amateur Canadian horticulturist, Mr. H. H. Groff, a banker, of Simcoe, Ontario, and for a good many years my experiments with the gladiolus were not renewed.

Meantime, every effort was made to exterminate the pestiferous gophers, whose depredations were of course not confined to the gladiolus, and through which I suffered an annual loss of certainly not less than a thousand dollars year after year.

Not alone with the gladiolus but with other bulbs it seemed that the animals took special delight in attacking the choicest plants. And the question of their destruction became finally a very urgent one.

Numerous methods of combating the pests were tested. A double box trap set in gopher holes was cumbersome and not very effective. An awkward iron trap was supposed to catch the gopher when he poked his nose against the trigger, but missed fire or failed to score a hit oftener than otherwise. One form of trap after another was

Another Group of Color-Variants

What could be more interesting than to experiment with the seeds of five flowers such as these? The seedlings would be sure to show the widest possible range of variation, and new varieties of almost any type of flower coloration that might be desired could be obtained by selective breeding tried and given up. Attempts to smoke out the animals proved ineffective, as the gopher instantly builds a wall to shut out the smoke.

Bisulphid of carbon, which gives off a poisonous, heavy gas, was tested with equal lack of success. About the only resource was the use of poison, commonly called strychnin, placed on a piece of apple, potato, or carrot, combined with the use of a wire trap, in the hope that if one failed the other might prove effective. But in spite of all these methods the gophers multiplied, mostly from neighboring fields, where their damage to ordinary farm crops was not so marked. A few years ago, however, a gopher gun was invented that practically solved the problem. This consists of a trap so arranged that when the gopher pokes his nose against the trigger a charge of powder explodes beneath the animal, killing him instantly by concussion.

This device proved more effective than all others. Sometimes 35 or 40 gophers were destroyed in a day about the borders of my gardens. And in a short time the gophers were so nearly exterminated that they ceased to be a pest.

When these old enemies of the bulbous plants were thus finally subjugated, after years of effort, I determined to take up again the cultivation of the gladiolus.

A Burbank Giant Gladiolus

This is a variety selected for size of the individual flower, rather than for arrangement of flowers on the stock. It illustrates the accentuation of size to about its limit, apparently, in the case of the gladiolus. Like all of Mr. Burbank's improved gladioli, this one is a very complicated hybrid.

In the meantime, the gladiolus had been much under cultivation elsewhere, and its general and special qualities had been greatly improved.

But there remained plenty of modifications that could be made to advantage, and in starting a new series of experiments I had no difficulty in discovering faults to be remedied.

Recent Work With The Gladiolus

One of the modifications, to which reference has already been made, had to do with the arrangement of the flowers on the stalk. My success in developing a race having the flowers arranged on all sides of the stalks has already been referred to. In taking up a new series of experiments, I attempted to improve on the earlier variety, by shortening the stems of the flowers, so that they were compelled to arrange themselves more compactly around the stem; by ensuring regularity of placement; and by diversifying the plant arrangement.

Some forms were developed having two ranks of flowers, one on either side of the stem. Other races were developed with flowers in four ranks; yet others with the flowers in a spiral. Meantime the individual blossoms were enlarged in size, and their stems shortened, so that, when grown in a spiral about the stem, they crowd one another, making practically a solid mass of petals.

Massed on the Stem

Contrast the gladioli in this picture with the isolated blossom shown in the preceding one. In the present case, selection has been carried out with an eye to improvement all along the line, but notably with the thought of producing bunches of gladioli that are solid masses of flowers. In many of these improved varieties, the flowers grow in a spiral about the stem, and make a solid mass of blossoms, as here shown.

The contrast in appearance of a stem of gladiolus flowers arranged on this new plant with the old form in which the blossoms grew only on one side of the stem, or at most on opposite sides, is very striking.

Attention was given also to the modifications of the form of the individual flowers. In one form, petals were developed that are broad and ruffled so that they overlap, and thus give the appearance of a double flower. In another form the tendency of the anthers to turn to petals was accentuated through selection until a double variety was produced; and in one or two cases the extra petals were added without affecting the natural organs.

In yet another form, and the one that I personally admire most, two flowers appear to be fused into one, so that twelve petals are presented instead of six. The variety was fixed so that the flowers on every stalk come in the same way, constituting a double flower of an unusual type.

Particular attention was also paid to the development of regularity of petal in the case of the double gladiolus flowers. Irregularity of petals may be attractive in such flowers as the rose and the carnation, but with the gladiolus the double blossoms are less beautiful than the single ones, unless the petals are very regular. I experi-

The New Blue Gladiolus

The gladiolus, like the rose and the poppy, seems to avoid the color blue. Mr. Burbank has succeeded, however, in bringing out the submerged hereditary factors for blueness that exist in this, as apparently in most other flowers. A long series of experiments in hybridizing and selection was necessary to produce this striking result.

enced no great difficulty, however, in making the petals regular, as well as increasing their number by selection.

Studies In Color

In the newer series of experiments, especial heed was given, also, to the matter of color variation, seeking for clear and brilliant colors of varying shades. The blending of shades, and the arrangement of lines, dots, and edges of different color on the petals were all carefully taken into account.

There is opportunity for skill in the blending of different shades in a flower of such diversity of color as the gladiolus, akin to the painter's skill in mixing pigments.

One learns that there are certain combinations that will produce disagreeable colors, whereas others will result in new shades of exceptional brilliancy.

The characteristics of each flower to be worked into a hybridizing combination must be carefully studied.

If, for example, we cross a yellow gladiolus with a white one, we are likely to get a dingy white that is by no means agreeable. The cross of a pale pink with a white form is likely to give us a still paler pink, which would not be regarded as an improvement. Again, from the blending

A Moth-Like Gladiolus

Here is a Burbank hybrid gladiolus that has been made to take on a rather curious form. Its broad, wide-spreading upper petals, combined with the peculiar coloration of the lower ones, give it a certain resemblance to a large moth in full flight. It is a rather striking illustration of the possibility of modifying the form of a flower of distinctly fixed type.

of two nearly white strains, you may get dark colors in unpredictable combinations.

By studying the combinations, however, and making rigid selection among the seedlings, it will be discovered that there are certain color tendencies that tend to be dominant, and that, as a rule, may be expected to repeat themselves in the hybrid offspring, overshadowing the less fixed colors. Still the races of gladioli are so blended, and the color factors in their germ plasm so mixed, that one may confidently expect to find new and interesting combinations among any large lot of hybrid seedlings.

Indeed, it is not necessary to make new crosses in order to get interesting new types, since, as we have seen, all cultivated races of gladiolus are hybrids that carry many racial strains, and hence manifest the tendency to vary that we have seen everywhere manifested by hybrids in second and later generations; the pioneer work having already been accomplished with nearly all our cultivated fruits and berries, and most cultivated flowers.

Nevertheless, it is of course possible to exert a directive influence through selecting parents for crossing, and further direction may be given by selection among the seedlings for any given color or combination of colors. So new races with unique color combinations may readily develop,

A White Gladiolus

Most so-called white gladioli are not really white, as a comparison with a pure white flower like the Watsonia would quickly reveal. By careful selection, however, Mr. Burbank has produced a variety of gladiolus that is really white, as this picture testifies.

and, even if these are not at once fixed, they can of course be propagated indefinitely by bulb multiplication. Here, as with other plants, all forms grown from the offshoots of a bulb will reproduce the qualities of the parent form, and a new race may thus be spread indefinitely.

Notwithstanding the great diversity of colors of the different hybrid races of gladiolus, there have until recently been no gladioli that could accurately be described as pure white.

Where so-called white varieties have appeared, they have a dinginess that suggests the presence of an underlying pigment; also there are spots, stripes, or featherings of other colors, especially on the lower petals. That the hereditary factors for pigmentation are really present in these so-called white flowers, is demonstrated by the fact, already noted, that in crossing two of these we may produce varieties that bear colored flowers.

But the fact that these crosses of white gladioli produce flowers showing a great diversity of color, suggests obviously, the possibility of sorting out among these offspring, in the second generation, some that contain only the hereditary factors for whiteness. I have made this attempt, and by rigid selection have produced a race of white gladioli which, when further perfected, will constitute, I think, an interesting acquisition. Already these are

Symmetrical and Attractive

This is one of the Burbank gladioli that has been developed for general symmetry of form and all-round attractiveness. The flowers are individually large, and their colors have great brilliancy and purity.

partially fixed, and other growers of gladioli have observed the same fact.

Already the white gladioli breed fairly true, and further selections, with reference to the perfection and fixation of the type, will give us a race of white gladioli that is sure to meet the approval of the public. But here as elsewhere there is danger that in selecting for one quality other qualities will be neglected, so that the flowers are not kept up to their best standard.

Hitherto there has been no blue color in gladioli, any more than in the poppy, except, perhaps, submerged in combination with some of the darker colors. And for this reason, it has been found by all growers of the plants far more difficult to produce a blue flower than any other color, and until quite recently nothing approaching the really blue gladiolus had been produced.

The first blue ones introduced were in reality more purple than blue. Nearly all hybrid varieties have shown lines of bluishness or smoky blue at times.

The first gladiolus that could really be called blue was the one sent out from Europe under the name of Hulot. This had a small flower, and in other respects resembled the older gladioli—a dark purplish blue in color. By crossing this with white varieties of large size, pale blue with extra large

The Largest of Their Race

These Burbank gladioli have been developed to the full limit of size, while retaining peculiarly attractive forms and exceptionally beautiful colors. Note also the un-gladiolus-like arrangement of the flowers on the stalk.

fine flowers were produced by me. Two years ago, one appeared of very large size, and perfect in all respects with a true blue color.

The crossing of the gladiolus presents no difficulties. It is merely necessary to cover the three-parted stigmas with pollen of the desired parent so thickly that bees and humming-birds cannot interfere with the experiment.

In working on a large scale, it is convenient to place rows of different forms that one wishes to hybridize side by side, so that pollen may be readily transferred from one row to another, in walking along the rows, each forenoon when the stigmas are receptive. Also this arrangement allows the hybridizing to be carried out by the humming-birds which are always aids in the fertilization of these tubular flowers. Here as in most other experiments, I have found that the results of the reciprocal cross are the same; it makes no difference which parent is the pollenate and which the pistillate member. So the seed from the contiguous rows of gladioli thus hybridized may be saved in a single lot.

My experiments with a new strain of hybrid gladioli have now progressed so far as to assure the development of some greatly improved varieties.

New crosses and rigid selection are giving

All Round the Stem

This is among the best of Mr. Burbank's improved varieties of gladioli for general cultivation. It has in large measure the good qualities of all the others, and is distinguished by the compact spiral arrangement of the flowers, which entirely hide the stem. This variety has well deserved popularity.

larger flowers, brighter colors, more compact stalks, and a tendency to multiply more rapidly from the bulblets—and especially with greater freedom from disease. The propensity to revert toward the original type of the wild species—small flowers, long slender stalks, closed blooms, dull coloring, narrow leaves, and poor constitution—is being subordinated as the selection is carried through successive generations.

And while there will be no metamorphosis in the essential characteristics of this beautiful and popular flower, further modifications of detail that are of no small practical significance may confidently be expected.

—We may well suppose that when the Gladiolus was finally brought to California, having been shipped first from South Africa to Europe and then from Europe half way around the globe, there was an added stimulus, urging the plant to still further modifications of habit, and supplying yet other elements of variation, such as form the basis of all plant development work.

Experimenting With The Responsive Dahlia

An Infinity of Variation Which Has Only Been Tapped

IF you have seen a Navajo blanket you are aware that the Indians of the Southwest are lovers of vivid colors—in particular of glaring reds.

It would appear that the insects of the same region have acquired similar tastes; for they have aided in the development of a good many flowers that advertise their wares with the most brilliant hues. The cactus furnishes a familiar instance.

Another example is supplied by the even more familiar dahlia, which in its native Mexican form had florets of bright red with a yellow center—supplying the basis for the modified color schemes of the dahlias now under cultivation everywhere.

The original red dahlia so attracted the eyes of the Spanish conquerors in Mexico that they sent the plant to Europe, and its reception there suggests that barbarian and insect have no monopoly of the color sense to which red appeals. For the Mexican composite flower was taken into the European gardens, and made to feel quite at home in its new habitat.

The new exotic came, as a matter of course, under the eye of the great classifier Linnaeus. And he thought so highly of it that he was moved to name it in honor of his friend and pupil, Dr. Andreas Dahl. The great Swedish classifier spoke with final authority in that day, and "Dahlia" the plant became in all languages and wherever grown—except, of course, in its native habitat; and what it might be called there, if anything, did not greatly concern the civilized world.

The scientific generic name Dahlia seemed to serve as well as another for the popular name also. So the name of the friend of Linnaeus has been perpetuated as a household word, familiar almost as the words rose or violet; but of course the great majority of people who pronounce it give no thought to its origin, and are quite unaware that they are paying tribute to a man, and commemorating a friendship, when they speak of this familiar garden flower.

So entirely has the origin of the word been overlooked, indeed, that the name dahlia, which should obviously be pronounced with the broad *a*, is universally pronounced with the long *a* in Eng-

A Cluster of Dahlias

The upper right hand flower suggests the form of the primitive wild dahlia, indigenous to Mexico. The other flowers show modifications due to hybridization and selection, of which we shall see numerous other illustrations in succeeding pictures.

land and with the short *a* in America, each branch of the Anglo-Saxon race seemingly trying to get as far away as possible, in different directions, from the natural pronounciation suggested by the derivation of the name, and its spelling—if indeed the spelling of a word in our language can be said to have any particular association with pronunciation.

Early Development of the Dahlia

All that, however, is of no great importance. A dahlia by any other name or pronunciation would be equally attractive. What is important is that this flower, brought from its sub-tropical home, proved wonderfully adaptable to its new surroundings, and showed a responsiveness to good treatment that presently transformed its general appearance, and gave it secure place in the group of three or four most popular flowers.

There are several species of dahlia, all natives of Mexico or the regions a little farther south. But the species that is chiefly responsible for the development of the new races, or at any rate those that first gained recognition in Europe, is one that because of its tendency to vary even in a state of nature was named *Dahlia variabilis*.

This flower, which was introduced into England in the year 1789 by the Marchioness of Bute, has the general form of a very large daisy and it resembles numerous familiar wild sunflowerlike composites, except that its floral envelope is dull scarlet with a yellow center, instead of being yellow or white.

We have seen a good many illustrations of the effect of transplanting a plant from one region to another. The dahlia furnishes yet another example. Brought from sub-tropical Mexico to the relatively cold climate of England, it soon showed the effects of altered climatic conditions. The tendency to vary was accentuated, and when in due course the plant was hybridized with other species brought from the same region, the hybrids took on such modifications as presently to produce races of dahlias so utterly divergent from the parent forms as to be almost unrecognizable.

Not even a botanist would associate the wild composite with its eight flat florets of ordinary shape and appearance, with the relatively gigantic rose-shaped flower made up of an infinite number of tubular florets packed together into a solid head.

The colors of the flower have been correspondingly modified, although the original red and yellow of *variabilis,* together with the white and crimson of certain other species, form the basis of the coloration of all the cultivated varieties.

And as to size of stalk, whereas the original

Bed of Dahlias

Here are seedling dahlias of mixed ancestry. Almost any number of new varieties might be developed from selections in this single bed. Only a few of them, however, will be thought worthy of further observation and testing by Mr. Burbank.

species rises to a height of seven or eight feet, there are dwarfed cultivated races that are only eighteen inches high.

In habit, there is a corresponding range of variation, some cultivated species requiring a large amount of moisture, whereas others thrive in a dry soil. Even the seed is of altered shape, and the time of blooming, which in the early part of the nineteenth century was said to be from September to November, has been so extended that some of the modified dwarfed forms are now in full flower in June.

In quite recent years a type of dahlias has been introduced in which the petals are less tubular but have a typical and characteristic tapering form. This is known as the cactus dahlia, partly because of the shape of its flower, and partly because of its brilliant scarlet color.

The original flower of this type was found in Mexico about 1879, and was named *Dahlia Juarezii,* after President Juarez, "the Washington of Mexico." The precise origin of the plant is unknown, but it is believed to be a variety of the original *Dahlia variabilis.* In any event the new type has been crossed with other races, and it now appears, like the others, in practically all colors, with the single exception of clear blue, this color alone being seemingly unwelcome to flowers of

A Primitive Type of Dahlia

The wild dahlias are sunflower-like plants that scarcely suggest the familiar cultivated dahlias of the flower garden. It will be seen, however, that the primitive type here shown manifests a tendency to variation in form of the "petals" (properly ray flowers), suggesting possibilities of development.

the tribe, just as it is to the poppies and the gladioli, both of which tribes show a range of coloration strikingly similar to that revealed by the dahlias.

New Forms and Combinations

My own experiments with the dahlias have largely had to do with flowers of the cactus type.

I have raised these by the hundred thousand, and have produced some really fine forms that have been introduced by Vaughan, Burpee, and others. The modifications introduced have been numerous, and some of them at least have constituted rather notable improvements, notwithstanding the elaborate development of this plant by many earlier workers.

In the course of my experiments I have endeavored to give a new impetus to variation and renewed vitality by hybridizing the cultivated forms with the species imported directly from Mexico. To be sure the dahlias originally in hand are so hybridized—to say nothing of the original tendency to variation—that there is plenty of material for selection in any lot of seedlings.

Still I have thought that I might gain some new combinations by the use of wild strains, and in this my expectations have been realized.

One of the faults of the dahlia, even in the best varieties, is that there is a tendency to expose the

Simple but Pleasing

The dahlias originally obtained in Mexico have been widely hybridized by horticulturists in Europe and America. The results are familiar to every lover of flowers. Mr. Burbank has gone back to nature, seeking wild species of dahlia for further hybridizing experiments. Here is a simple but pleasing specimen that has been utilized in some of his recent tests.

center of the flower, owing to the fact that not all of the stamens have been transformed into florets even in the most developed varieties. The result is that in a dry summer, or toward the end of the season, even good varieties may fail to show the fully rounded head that is prized by the connoisseur.

I succeeded through selection in overcoming this defect, causing the heads to fill out altogether, so that they were double to the very center, even at the end of our dry California seasons. A number of varieties were thus perfected, and these were, I believe, the only entirely double dahlias that were ever produced.

As the ideal sought was approximated, the flowers produced less and less seed, and the perfectly double ones produced none at all.

So the races thus developed must be propagated altogether from the bulbs. This, indeed, is not an insuperable objection, inasmuch as this is a common way of propagating the dahlia. But of course there is always an added merit in a garden flower that can be produced from the seed.

It is well-known, however, that even the best-fixed races of dahlias are not expected to breed true from the seed. Like other specialized flowers they carry too many hereditary strains in new combinations to be expected to breed true to any

Tending To Vary

The wild dahlia evidently had unusual propensity to vary; otherwise it would hardly have been possible to develop the extraordinarily complex flowers that are now to be seen in our gardens within the comparatively short period of time since the dahlia was brought under cultivation. Here we see illustrated the tendency to variation even among flowers growing from the same stem.

single type. So while the dahlia is constantly raised from the seed, it is always to be expected that the seedlings will show a wide range of variation.

It is only in specimens grown from the bulb that any certain prediction can be made as to the precise characteristics of the prospective flowers.

One of my beautiful yellow double dahlias has shown a curious responsiveness to the diverse conditions of soil in the gardens at Santa Rosa and at the experiment farm at Sebastopol only seven miles distant.

At Santa Rosa the plant grows to a height of about three feet, and resembles the common types of dahlia as to its general maner of growth, though an unusually profuse bloomer.

But at Sebastopol the plant is a dwarf, not exceeding two feet in height; and as it retains its habit of profuse blooming the dwarfed form looks like a solid bouquet of cut dahlias.

Similar modifications in the size of plants, but less striking in degree, are of course common enough under differing conditions of soil, and in particular with varying moisture. But of course such variations do not affect the heredity of the plant appreciably. They have no relation with the production of dwarf and gigantic varieties in the same fraternity through hybridizing, of which we have seen examples among various races of plants.

Still Wider Variations

The dahlia is a composite flower, and its "petals" are in reality ray-flowers. We have seen in earlier pictures how these ray flowers attempt to vary. Here they have seemingly run riot. The result is an asymmetrical flower which, however, is by no means lacking in artistic attractiveness.

A Stage of Progress

This hybrid dahlia from Mr. Burbank's colony probably illustrates one of the stages through which the cultivated dahlias have passed within comparatively recent generations in the course of their development. Here, it will be seen, the ray flowers are encroaching on the center of the flower head, and the contrast between this double flower and its wild prototype is very striking.

With all its attractive qualities, the dahlia is not quite a perfect flower because it lacks fragrance.

This defect also I have sought to remedy, and as regards the mere matter of production of a fragrant dahlia, have been entirely successful. Unfortunately the new fragrant races have not hitherto combined odoriferousness with the qualities of size and form and color that enable them to compete with the best standard varieties. Still, enough has been done to show that with further effort the dahlia may be given a perfume that will greatly enhance its attractiveness.

Races of Fragrant Dahlias

In endeavoring to develop a race of fragrant dahlias I followed the same rules of selection that have been repeatedly outlined.

The first thing was to find an individual that revealed even the faintest pleasing aroma. In general, dahlias have either no odor, or a slightly disagreeable one. The tribe of composite flowers to which the dahlia belongs depends as a rule upon the conspicuous floral envelope to attract the pollenizing insects, and has not developed fragrance.

But it is probably true with regard to fragrance as with regard to combinations of colors that there are unrevealed hereditary factors in the germ plasm of almost every flower. The production of

An Interesting Seedling

This hybrid seedling has not departed very widely from the traditions of its ancestors, but it presents a peculiarly pleasing appearance, on account of the form and wave-like effect of its ray flowers. It will doubtless be utilized for further breeding experiments.

odoriferous oils and essences is so characteristic a phenomenon with plants in general, that we can hardly doubt that every tribe has in its ancestral strains very complex elements for the production of odoriferous compounds. Odors appear to play a very important part in plant life, not merely in the attraction of insects to facilitate cross-fertilization, but also in giving plants protection.

Otherwise it would be hard to account for the almost universal prevalence of odors of one kind or another in connection with the various tissues of the plant.

Moreover there is a far closer relationship than is commonly supposed between agreeable and disagreeable odors. Ottar of roses, properly diluted, has a delicious fragrance; but the same essence in its concentrated form is positively disagreeable. Also the combination of disagreeable odors sometimes produces a delightful fragrance in the hands of the perfumer.

This may give the clue to the rather puzzling fact that even among fragrant flowers there may be found occasional blossoms that have a more or less disagreeable odor. By eliminating these, the quality of the odor of a bunch of flowers is greatly bettered. Yet many persons gather flowers indiscriminately without realizing why some bouquets have more agreeable odor than others.

A Dahlia of the Cactus Type

Dahlias of this type, with tubular and pointed ray flowers are familiar in our gardens. Here, as in the other pictures shown, Mr. Burbank is experimenting with more primitive types of dahlia, and seeking to develop new propensities. He has produced a large number of improved varieties of the conventional types; but his newer experiments, as already stated, have to do with species and varieties that have been less extensively cultivated.

Making application of a knowledge of this affinity between disagreeable and agreeable odors, I searched diligently among dahlias of various races for a long time, hoping to find one in which the disagreeable odor was supplanted by an agreeable one.

And at last the search was rewarded. I found a dahlia that had a faint but very pleasing fragrance comparable to that of magnolia blossoms.

Of course the seeds of this plant were saved, and in the following season the most careful search was made among the plants that grew from them for fragrant flowers. And, as might be expected, a certain number of these were found.

By repeated selection, always searching for the most fragrant flowers, and carefully saving their seed, a race of dahlias was developed many of which had a very agreeable perfume. Rather I should say that there were several races, for the quality of fragrance was associated sometimes with one set of characteristics of size and form and color, and sometimes with another.

Selection being made in this case for fragrance alone, as was necessary in order to intensify this evasive quality, it was necessary mostly to ignore the other qualities, and as usual in such cases, it resulted that the new fragrant races of dahlias, while having perfume that recommended them,

Dahlia Variations

This picture gives a very good idea of the range of variation among the materials with which Mr. Burbank is now working. It is obvious that here are fascinating possibilities of development in many directions. Some very striking and popular varieties will doubtless result from the further utilization of this material in Mr. Burbank's gardens.

were somewhat lacking in the other qualities. The great popularity of the flower has led to such perfectionment of its various characteristics in recent years that the standard of competition is very high, and it would be useless to introduce a new variety that did not measure up in all regards to the existing varieties.

So up to the present time the fragrant dahlias have not been introduced, except three or four, which were purchased by Vaughan, of Chicago.

Further experiments in selective breeding, aided probably by hybridization, will be necessary before the quality of fragrance is combined with satisfactory qualities of size and form and color. But, as I said, there is every probability that these combinations will be effected in due course, and that races of dahlias which combine all the qualities for which the flower is now prized, with the added quality of pleasing aroma, will be available.

Wider Hybridization Attempted

We have seen that the experiments through which the original wild dahlias were transformed into gorgeous double flowers of a characteristic type utilized the principle of hybridization at all stages. In my own experiments, I have attempted to extend the principle, not merely to all the flowers of the genus, but also to those of allied genera.

More Chips from the Dahlia Workshop

This picture should be compared with the preceding one, and with the two that follow. Taken together, these pictures give a realizing sense of dahlia possibilities. Such variations as these may be found in a comparatively small colony grown from the same lot of seeds. Of course they are very complex hybrids.

According to the estimates of the botanist, the dahlias have fairly close relationship with plants of the genus *Bidens*. Indeed, a familiar species of the genus, known as *Bidens atrosanguinea,* a tuberous variety with dark purple flower, is often spoken of as the black dahlia. Its tubers and foliage strongly suggest the common dahlia in miniature.

For four or five years I worked extensively with this so-called black dahlia, not only by way of improving the flower itself, but also in the attempt to hybridize it with the dahlia proper.

I succeeded by selective breeding in enlarging the flower to about twice its original size, in making the petals much rounder and fuller, in adding extra petals, and in changing the color of the petals from the usual dark purplish crimson to a light crimson approaching scarlet and in a few cases to a pale pink approaching white. The bush itself was also made more compact.

All these changes were produced by selection and re-selection, working constantly toward the new colors desired, and toward increase of the size of flower, and modification of form.

The species worked with was a Mexican form. There is an aquatic form with large, brilliant, yellow flowers, closely related to the species known in the east as "pitchforks."

Experimental Only—Yet Not Lacking in Beauty

Some of these experimental dahlias are really handsome flowers, as a glance at the pictures suggests. But none of these will be introduced, until the possibilities suggested by their wide range of variation have been more fully realized in their progeny.

For two or three generations, the flowers seemed fixed. I could see no change whatever; no tendency to break into new forms. I attempted to hybridize the two species of bidens, but did not succeed, so it was necessary to depend upon selection alone. The plants were grown in large quantities. After several years, slight variations appeared; and then, as in so many cases, the tendency to variation became somewhat accentuated.

I became convinced that the black dahlia and other species of bidens are well worth cultivating, and that some other valuable tuberous flowering plants could be developed from them that would be welcomed by flower lovers in general.

But other engagements made it impossible for me to carry the experiments beyond the early stages.

And as to the matter of crossing the bidens with the dahlia, in which I had been especially interested, the result was altogether negative.

Repeated efforts failed to fertilize either species with the pollen of the other.

Notwithstanding the outward similarity of the plants, it would appear that their racial strains have diverged beyond the point of ready commingling. Still it is possible that a more extensive series of experiments might have met with better results, and further efforts along the same line are

Approaching Perfection

Some of the specimens here shown are approaching their limit of probable development in a certain direction. But note how strikingly different these flowers are from the familiar double dahlias of our gardens. To casual inspection they would scarcely seem to belong to the same genus of flowers. Yet these hybrids have at least some strains of heredity that are identical with those combined in the familiar double dahlias of our gardens.

at least worth making. Could a cross be effected, we might reasonably expect some very interesting modifications in the hybrid product; notably, perhaps, an accentuated capacity for growth that would possibly give us dahlias rivalling the largest crysanthemum in size, as they already rival it in form and flexibility of petal-like florets.

Cross-Pollenizing The Dahlia

Among themselves, the dahlias cross very readily, it being, indeed, difficult to keep them from crossing when they are grown near together.

Yet, as in the case of all composite flowers, the hand-pollenizing of the dahlias presents certain difficulties. The method of hand-pollenizing, with special reference to the washing off of the pollen from the pistillate flower before applying the foreign pollen, has been detailed in its application to composite flowers in general in the chapter on pollenization. It may be added that it is sometimes possible to blow the pollen away, if water for washing it off is not available. The use of a strong magnifier to inspect the receptacle and make sure that all pollen has been removed will give added certainty to your experiment.

After the pollen has been thoroughly removed by washing, apply the head of the flower that is to be used as the pollen parent, rubbing it gently against the pistillate head while it is still wet.

Color Variation at Its Limits

Composite flowers usually arrange the colors of their ray flowers symmetrically. But here is a dahlia that has departed strikingly from the traditions of its tribe, presenting some petals that are striped and others that are of uniform color. It would be interesting to observe the range of color variation that would be shown by the plants that might be grown from the seeds of this single flower.

But to complete the experiment, it is desirable to mark the flower, and to repeat the manoeuvre on several successive days. This is necessary because not all the flowers in the head mature at the same time. The outer come to perfection first, and the process of maturing advances towards the center of the flower. So the first pollenizing must be done just at the right time, and successive pollenizings day by day until the entire flower has come to maturity, if all the pistils are fertilized.

It is obvious, then, that the crossing of dahlias, while it presents no real difficulties, and is tolerably sure in its results, is a somewhat tedious and laborious process where the field of operations is wide. But, as already pointed out, it is not necessary for the experimenter who is seeking merely to modify existing varieties to resort to hand-pollenizing.

The varieties that will appear among any ordinary lot of seedlings will afford him ample opportunity for selection.

On the other hand, the experimenter who wishes to develop new types of striking individuality will of course crossbreed the old ones, using species or varieties as widely separated as possible. My own experiments, as already pointed out, have involved the use of wild species from Mexico, and the influence of these wild crosses has undoubtedly been felt in the rather striking results attained in working with a race of flowers that, despite its comparatively recent advent in the horticultural garden, is already highly specialized.

That further improvements of striking character will be attained can scarcely be doubted by any one who takes into account the fact that the dahlia is a parvenu among the admitted aristocrats of the flower garden. It is impossible that the hereditary resources of any plant should have been exhausted within the comparatively brief period of time that has elapsed since this extraordinarily responsive and adaptable flower was first brought from the wilds.

—Brought from sub-tropical Mexico to the relatively cold climate of England, the dahlia soon showed the effects of the altered climatic condition. The tendency to vary was accentuated and presently there was a new race of dahlias, so utterly divergent from the parent form as to be almost unrecognizable.

The Wyoming Canna

Mr. Burbank has had great success in the development of the canna, introducing a number of varieties that have gained popularity. The one called the Wyoming, here shown, has flowers that are peculiarly graceful and attractive.

The Canna and The Calla

And Some Interesting Work With Lilies

MY most celebrated canna is the one named the Tarrytown. This canna took the grand gold medal at the Pan-American Exposition at Buffalo, as the best canna exhibited at that time. There were large numbers in competition.

In addition to receiving the gold medal, the Tarrytown was given special mention as being the most profusely blooming canna ever seen.

The new canna is a rich brilliant crimson in color, and is rather dwarfed in size, standing not higher than three feet. Instead of producing a single stalk or at most three or four stalks, as a good many even of the better varieties of canna did at the time when this was produced, the Tarrytown grows from six to nine off-shoots of the main stalk. Thus it makes a splendid and highly effective display.

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The individual flowers are of good substance, enduring the sun well.

After the blossoms fade, the petals drop to the ground. This is a special feature for which careful selection had been made, as many cannas tend to hold shrivelled blossoms, thus having an untidy appearance.

Origin of the New Canna

The Tarrytown canna was developed from the type known as the Crozy canna, hybridized with a native species of the Florida swamps known as *Canna flaccida,* a plant with extremely large flowers of pure lemon yellow.

The Crozy canna is a well-known horticultural variety, developed in somewhat recent years, which differs from the varieties that were previously in vogue in that its flowers are notable attractive and of varying colors. Until the cannas of the Crozy type were developed, this plant was prized chiefly for its foliage, the flowers being rather insignificant. But the Crozy canna has large flowers, to casual inspection similar to those of the gladiolus.

The Florida species (*C. flaccida*) that was used to hybridize with the Crozy, has very fine large petals, but the flowers are not lasting. But it blended well with the other type, and introduced an element of variability that facilitated selection

An Experimental Canna

Mr. Burbank's cannas are hybrids, in which the strains of the cultivated species have been mated with those of a wild species from Florida. The specimen here shown illustrates a stage of progress.

and development along the lines similar to those characterizing the perfected Tarrytown; also the Burbank, Austria, and Italia, since introduced.

The Crozy canna is itself a hybrid, one of the parents, I believe, being a form known as *Canna iridiflora,* a tall plant with long, dark green leaves, and with a long drooping panicle of rich crimson flowers. I have experimented with this form, but have never known it to produce seed. The developer of the Crozy was apparently more successful in this regard, and in going forward with the experiments I was enabled to profit by the earlier hybridization.

The new hybridization that I effected between the Crozy hybrid and the native Florida species, brought together strains widely diversified; for most of the cannas are of tropical origin. The tendency to variation was very obvious even in the first generation, as might have been expected considering that one of the parents was itself a hybrid.

From the same hybrid strain it was possible to select a number of plants showing individual peculiarities that seemed worthy of perpetuation.

The qualities developed in the Tarrytown have already been outlined. Another race developed simultaneously, through a different series of selections, differed very markedly, in particular as regards the character of the flower, which took on so characteristic a form, and colors of such elusive quality, as to merit the name of Orchid-flowered Canna. It chanced that experimenters in Italy produced simultaneously and quite independently a race of canna having closely similar qualities.

The best of my cannas of this type was introduced under the name of The Burbank.

This plant rather closely resembles a variety known as the "Austria" which was introduced about the same time from Europe. The Burbank, however, is somewhat larger, and has thicker and more rubber-like foliage; and its flower its slightly less crimson in the throat.

Working With The Canna

The cross-fertilization of the canna should seemingly present no particular difficulties to anyone who studies the mechanism of the flower.

The stamens have a petal-like appearance, and the pollen-mass could not be transported by the bee or any other small insect. Large moths may carry it from one flower to another, but the usual pollenizer of the canna, in this country, is the humming-bird.

The hand-pollenizer may readily enough detach the pollen-mass, and transfer it to the stigma of another flower.

But it does not follow that hybridizing is easy.

An Improved Canna

This variety shows marked improvement over its progenitors, but it does not fully compete with some others in Mr. Burbank's colony, and so will not be introduced. It has been utilized, however, in further breeding experiments.

In point of fact I found it exceedingly difficult, especially when attempting to cross the ordinary canna with the Florida species already mentioned. I worked for eight years with that purpose in view before succeeding. And even then the seedlings were greatly lacking in fecundity, producing very little seed, notwithstanding the fact that cannas in general usually produce abundantly in California.

The infecundity of the canna hybrids suggests that the species in question are almost at the limits of affinity. But the seeds produced, although few in number, were some of them fertile, and the hybrid progeny showed possibilities of development, as already suggested. The later generations, however, are almost or quite sterile, refusing to seed.

The chief difficulty in growing seedlings of the canna is to insure the germination of the seed. The familiar name "Indian-shot plant" by which the canna was first known suggests the character of its seeds, which in point of fact are not unlike small bullets in appearance and in hardness of texture. The old plan of germinating the seeds used to be to file off part of the thick shell, in order that the seed might absorb moisture.

This works very well, but can hardly be applied on a large scale.

My own method has been to disinfect the canna seed with a solution of blue stone (sulphate of copper), and place them in coarse gravel, taking pains to pour water through the gravel at frequent intervals. Under these circumstances, the seed is less likely to decay through attacks of fungous pests than if planted in the soil. In the coarse, clean, sterilized gravel, a high percentage of the seed will come up in a few months. The porosity of the gravel, giving free access to air, is also an element that is advantageous to the seed of the canna.

Seed treated in this way will germinate at a relatively low temperature; but germination is facilitated if the heat is kept between sixty and seventy degrees.

As soon as the seedlings appear, they are transplanted thinly into boxes where they are allowed to stand until May, when they are planted in the field, and cultivated like other crops.

A large proportion of the seedlings will prove worthless. The weeding out of the first year is done readily, but selection in the second year requires skill, to judge as to which plants are worthy of preservation. Beyond that, of course the usual process of selection through several generations will be carried out along the lines of the desired modification at which the experimenter is aiming.

The objects that the experimenter may advantageously bear in mind in developing new cannas,

The Burbank and Tarrytown Cannas

These are two of the best of Mr. Burbank's improved cannas. They have been introduced, and have attained great popularity. Though so different in appearance they are of kindred origin, both being hybrids developed by crossing cannas of the Crozy type with a native species from Florida, the latter a plant with extremely large flowers of pure yellow.

include hardiness, the production of a double flower, and the production of a white flower, among others.

In California the canna may be left out of doors over winter; indeed it does much better when so treated than when the bulbs are lifted and stored. In the northeastern States, it is necessary to dig the roots and store them where they will not be subject to too low a temperature. It will be of advantage to develop the canna to a stage of hardiness that would enable it to be treated as an ordinary perennial, leaving the roots in the ground and only dividing them now and again for purposes of propagation. Still this might require more work than is worth giving to the task, inasmuch as the canna is already grown far to the north, and the work of digging and storing the bulbs is not excessive.

A double canna would certainly be a novelty and one that is probably worth working for. The same is true of a pure white canna. By hybridizing and careful selection, it should be possible to develop this novelty, judging from analogy with other flowers. Of course it is possible to increase the size of the flower, and to produce other color variations along the line of recent developments. Most important of all, the flower should be made more lasting.

The manner of production of my fragrant calla was described in an earlier chapter.

It will be recalled that this anomaly was produced through selection from an individual found among a large company.

The question of odor and its variation in flowers was further discussed in a recent chapter. There appears to be, in point of fact, as wide a range of variation among flowers in the matter of odor as in regard to color. But inasmuch as most selective experiments have been made with reference to color and quite without regard to the matter of odor, the cultivated plants have naturally developed along the lines of color variation, and even those that were originally fragrant have in many cases lost their perfume.

Improving Essential Oils

In recent years, however, much more attention has been paid to this matter. In particular, the studies of the chemistry of essential oils, with reference to the production of artificial substitutes for the natural ones, has given clues that the plant developer is beginning to take up.

I have been invited, for example, to improve the clove and the cinnamon, as well as the coffee plant, in the production of races having a higher percentage of the various essential oils for which they are prized.

An Unnamed Canna

The cannas have a characteristic type of flower from which there is no very wide range of variation, even among the hybrid seedlings. As to size, color, and arrangement of blossoms on the stems, however, there is considerable opportunity for choice. The specimen here shown suggests interesting possibilities, although not itself considered worthy of introduction.

Coffee, as everyone knows, depends very largely on its aroma and fragrance, and it has been found that these may be greatly modified according to the soil in which the plant is grown. The fragrant qualities are often greatly intensified when the plant is grown on volcanic soil and at a high altitude. It is known that various spices differ markedly. In the same way the quantity of alkaloids, such as caffeine and quinine, may vary in the same species under different conditions of soil and climate. There is a species of coffee that is practically without caffeine; but this has little aroma. It has been proposed to combine it with the Arabian coffee and it may be possible to produce a coffee without caffeine—which may or may not be popular.

Among garden plants that are prized for their aromatic quality, the thymes vary widely in the amount and quality of their essential oils.

The notable variation in the odor of the calla, which gave me my scented variety, is duplicated in a good many species of lily.

The individuals even of the wild species vary, some of them having a really delightful fragrance, and some none at all. In crossing the different individuals, you may accentuate the perfume, add one element of fragrance to another; or, on the other hand, you may make such a combination that the two aromas seem to neutralize each other, producing an odorless hybrid.

The plant developer who works with these anomalies in mind, paying heed to the fragrance of his flowers as well as to their other qualities, is almost certain to produce varieties that will be appreciated, for, as already suggested, the perfume of the flower and the flavors of foods are nowadays receiving more attention than formerly.

New Giant Callas

I have introduced four main varieties of calla in addition to the calla Fragrance.

My work began largely with raising seedlings for the trade, from the form of calla known as *Richardia albo-maculata,* a dwarf variety with spotted leaves that was at that time very popular.

The leaves of this plant bore attractive white or transparent markings on the bright green surface. The flower was white, with a brown tinge at the base, and in the original form was insignificant.

I raised this calla in great quantities a good many years ago, sometimes producing from the seed a quarter of a million bulbs in a season.

Among these almost numberless seedlings appeared, now and then, a golden variety, but this proved difficult to fix, although very handsome and attractive.

Presently I secured another variety of calla

Another Experimental Canna

Here is a hybrid canna with a large flower of very pleasing appearance. It does not surpass the improved varieties already introduced, however, and it will be used only in further breeding experiments.

known as the Pride of the Congo, *Richardia hastata.* This is a much stronger grower than the other variety and has pale yellowish flowers larger than those of the *albo-maculata.* I raised many seedlings from this variety on my Sebastopol place, and developed it by selection until it produced very large bulbs.

Then I hybridized the two species, using our hybridized golden variety of the *R. albo-maculata* and the developed varieties of *R. hastata.* The cross was made reciprocally as usual, and here as elsewhere it appeared to make no difference which was the pollenate and which the pistillate parent.

The hybrids vary considerably as to bulb, plant, and flower—much more so than either parent species when raised from uncrossed seed. And among the hybrids there were some plants that produced enormous bulbs, sometimes eight or ten inches in diameter and weighing from two to six pounds each. The plants that grew from these bulbs were of large size and bore blossoms that were of much brighter yellow than those of either parent.

This plant was introduced under the name of the Giant Calla, a name subsequently changed to Lemon Giant.

Subsequently I obtained a number of other species of calla, including those known as *R.*

Elliottiana, R. Pentlandi, R. melanoleuca, R. Nelsonii, and *R. Rehmanni.* These were all hybridized with one another, and with the species that previously was in hand.

Among these complex hybrids were plants that were unique in form and foliage and flower.

The blossoms varied in color not only in the different hybrid plants, but sometimes an individual blossom would be partly deep purple, partly deep yellow, and in part almost white. Sometimes the colors were mottled or orange in stripes, but usually the purple color appeared in the throat of the flower.

The purple is apparently a combined inheritance from the *Elliottiana, Rehmanni* and *melanoleuca;* and the *hastata* also has a faint touch of it. The yellow is heritage from *hastata* and *Elliotiani.*

These plants varied as much in size as in quality of flower. Some of them grew three and a half feet in height, others only eight or ten inches. In some cases the foliage and stalks were smooth and in others actually hairy, covered with soft excrescences of thorn-like appearance. Some of the hybrids were very easy to raise, but most of them very difficult.

Among the freak forms that appeared in this hybrid colony were plants bearing double and even triple flowers, and others in which the flowers and

King Humbert Canna

This is a very pleasing variety of canna, the characteristics of which are well revealed in the above picture. The blossoms are individually of large size, and they are borne in profusion.

leaves were combined in the most curious manner. Of course the so-called flower of the calla is a modified leaf that has not altogether lost the leaf-like form and manner of growth. So the reversion through which the flowers become still more leaf-like in these mixed hybrids was prehaps not altogether surprising. But the particular manfestations of the tendency to reversion were most astonishing.

Other New Varieties

Among the hybrids that departed less markedly from the calla traditions, were some that bore flowers of a splendid deep yellow, and that had all desirable qualities of easy multiplication and abundant blooming.

Some of these have a purple spot low down in the throat, others are a pure yellow, not dissimilar in appearance to my early varieties.

But while the new hybrids outwardly resemble some of the early varieties developed by selection, they showed their inherent difference in that they are exceedingly easy to cultivate, whereas the earlier ones were subject to decay without apparent cause at any season of the year. The new hybrids are hardier, and can be raised much more readily. They will grow out of doors in any mild climate, and require scarcely more attention than so many potato plants. They are reasonably in-different to the conditions of moisture and a moderate degree of cold does not in the least discourage them.

The contrast in this regard between the newer hybrids and the earlier yellow varieties is very striking. They furnish an illustration of the added vitality that may come through hybridization.

The original yellow calla is confined to a limited area in the sub-tropical regions of South Africa. Its pure-bred descendants, as we have seen, retain the sensitiveness of the parent. But the selected hybrids, while retaining the yellow color of the African plant, have acquired from their other parental strains a degree of hardiness that adapts them to our climate, and at the same time have received increments of vigor that nothing but hybridization appears to give.

As to the later point, I may mention a sport that appeared among my white callas, in the form of a plant that grew to gigantic size. The sport appeared among the seedlings of the common calla but doubtless represents a natural cross between different strains of this species.

The plant bore its flowers on stems sometimes six feet or even more in height. The foliage was of corresponding size, and the flowers almost proportionately immense.

The new sport was named the Giant Calla.

A Bed of King Humbert Cannas

Most gardeners experience difficulty in growing cannas from the seed. Mr. Burbank's method is to sterilize the seed and put it in sterilized gravel for germination. He does not find it necessary to file or otherwise to treat the individual seeds, as is sometimes done by florists, owing to the hard shell. The picture shows the thrifty character of a bed of King Humbert seedlings.

In contrast with this giant is a dwarf of the same species, retaining the characteristics of the calla, and having the peculiar interest that attaches to a miniature flower reproducing the qualities of a familiar flower which we ordinarily think of as being of large size. Some of my dwarf varieties, produced by selection, have flowers only two inches in diameter.

Among the offspring of the Giant Calla, one has appeared that has a shade of purplish crimson on the stalk and blossom. This color I have never known to appear in the common calla before, and its appearance suggests reversion to a very remote ancestor. It is possible that the giant bears blood of one of the other species, two or three of which, as before mentioned, have strains of purple in their heredity but this is unlikely, as I have never been able to get these species to cross.

It will appear that there is abundant opportunity for the making of interesting experiments with the different races of callas. As to the practicalities of cross-pollenizing, there are no difficulties, notwithstanding the very curious character of the floral envelope. The calla flowers, as is well-known, are very tiny, and borne on the central spadix that stands like a little post in the center of the leaf-like spathe that is ordinarily thought of as constituting the flower.

To effect cross-pollenization, it is first necessary to amputate the spadix, removing the upper portion, with the staminate flowers.

Pollen gathered from another spadix may then be dusted with a camel's hair brush over the pistillate flowers at the base of the amputated spadix. Of course no attempt is made to operate on the individual flower; but the group as a whole may thus readily be fertilized.

As the pistillate and staminate flowers on any given spadix ripen at different times, there is no danger of self-fertilization if the operation of removing the upper part of the spadix is performed at the right time.

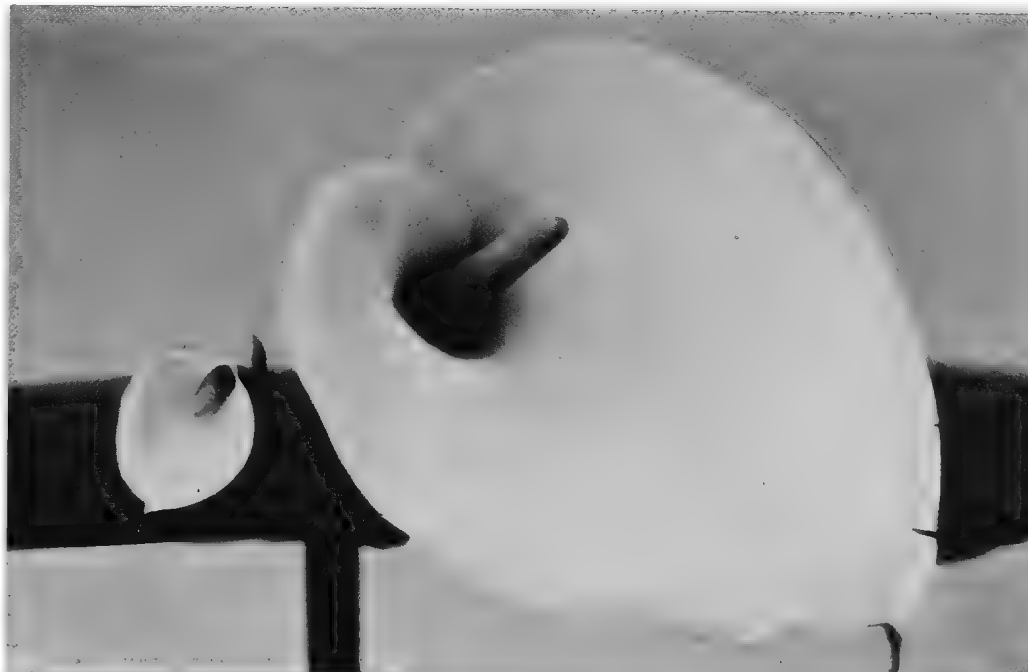
Common Lilies

To a fair proportion of country folk, anything that is not obviously a pink or a rose is characterized as a lily.

And in point of fact the diversity among the lilies and allied species is so great as almost to justify the wide implications given the name colloquially. A gigantic calla and a tiny trillium, for example, seem about as far removed from each other as two flowering plants can well be. And the most familiar forms of the tiger lily, which may perhaps be said to be the typical member of its tribe, assuredly bear small resemblance to either calla or trillium.

Giant and Dwarf Callas

Mr. Burbank has developed the flower of the calla in both directions. He has produced both giants and dwarfs. The one at the left in this picture is perhaps the smallest calla ever developed. Its spathe measures only two inches across.



Nevertheless there is a large group of lilies that bear greater or less resemblance to the typical species, having characteristics of form, no less than of arrangement of stamens and pistils, that are quite unmistakable to anyone having the slightest botanical knowledge.

A large number of these may be hybridized readily, and I have personally worked with a great number of species. But while the results have in many cases been interesting, they have not been very spectacular, or very important, and it is not necessary here to go into details with regard to most of them. It will suffice to tell of two or three typical hybridizing experiments made chiefly with the native leopard lily (*Lillium pardalinum*) as the pistillate parent.

The extent of my experiments with the tribe may be gathered from the statement that at one time on the two Sebastopol farms I had fully five hundred thousand more or less distinct kinds of hybrid seedling lilies. About three-quarters of them were produced by pollenizing the native species just named with all the species from different parts of the world of which I could obtain specimens.

I found that hybrids between the numerous species of lilies that are native to the Pacific Coast could be made with the greatest facility. Tens of thousands of seedling hybrids between the different indigenous species were produced. But, on the other hand, hybridization with the foreign lilies was found to be rather difficult, different species having seemingly diverged somewhat toward the limits of affinity.

One of the most successful crosses was that made between the species known as *Lilium Humboldtii* and *L. parryi*. The former has a very large bold, thick petal, white, with large distinct spots, and it is fragrant. The other parent is a tall, slender variety, the flower being clear buttercup yellow, with very small spots or none.

The cross was made with some difficulty, and the result was a lily which some connoisseurs have considered one of the most beautiful ever developed. It grows about four feet in height, and its flower is open bell-shaped, with partially curved petals, brilliantly yellow in color, without a spot or dot, and having a delightful fragrance.

Another interesting cross was that between *L. pardalinum* and *L. parvum*. The hybrids of this cross sometimes produce hundreds of blossoms on a single stem, and several hundred clumps from a single bulb. Not only do they multiply with astonishing rapidity, but in size, color, and abundance of bloom they exceed either parent, although both parents are prolific bearers.

The Fragrant Calla

The story of the development of the fragrant calla is told in detail in an earlier volume. The reader will recall that the scented variety was developed through selective breeding, the ancestor of the race being a chance "sport" that had a trace of fragrance.

The crosses of the somewhat fragrant *L. parryi* with *L. Washingtonianum* and *L. pardalinum* produce bulbs having similarly extraordinary powers of multiplication, although in this regard there was a most amazing variation. Certain individuals would produce a hundred bulbs while others of the same fraternity were producing only one or two.

Some of these seedlings would grow eight or ten feet in height, while here and there would be one from the same lot of seed growing only eighteen inches or two feet in height.

But the most striking characteristic of these hybrids was their exquisite fragrance. Even though the seed were grown from *L. pardalinum*, which is never fragrant, the hybrids having the *L. Washingtonianum* cross for the other parent, were so fragrant that when massed together their perfume saturated the air, and could be distinguished, down wind, at a distance of several miles.

The individual plants differed widely on close inspection as to their forms and colors, but when viewed from a distance the effect was that of a great gorgeous spread of cloth of gold.

The variations in form of stem and flower among these hybrids extended also to the bulbs, some of which were flat and of varying colors, from pale rose and crimson to yellow, and others of which were compact, resembling pears or apples in form.

Another striking peculiarity of the bulb was that some of them had scales that were solid, as in the *Washingtonianum*, while in others of the same lot the scales would be divided into several separate divisions, each of which would grow a form of new bulb under proper conditions. Some of the bulbs when exposed to sunlight would turn to a brilliant crimson, while others after exposure for any length of time were white or yellow or variegated. There was similar variation as to the resistance to decay.

I may add that some of the little bulbs, notably those of *L. Brownii*, are edible and are considered a great Christmas delicacy by the Chinese, who make most delicious stews and soups from these bulbs. I myself have eaten the bulbs of *L. Brownii*, grown on the Sebastopol place, and have found them to have a most delicious oyster-like flavor. The possibility of these lilies as food producers have not hitherto been given the attention they deserve. All these lilies have bitter bulbs, and they are fairly resistant to eel worms, milliped, and thrip, etc., whereas the *Brownii* is invariably destroyed in the second year, and can only be grown in new soils. All the true lilies finally succumb on old soils. I have tried to eliminate the

The Lemon Giant Calla

Mr. Burbank's calla experiments have had to do with a number of species, which have been variously crossed. Here is an improved variety, produced by hybridization and selection, that was introduced under the name of the lemon giant. The flecked leaves, together with the quality of the flower itself, give it distinction.

bitterness through crossing but got no favorable results.

Some Wider Hybridizations

It has already been stated that the California lilies do not cross readily with the foreign species. Nevertheless I have made successful hybridizations in many cases.

Among the most interesting of these crosses was one in which the so-called Lily of the Incas (*Alstroemeria*—not a true lily, having no bulb), of South America, was crossed with the familiar California species (*L. pardalinum*), already so often referred to.

Of some of these hybrids I raised a large number, and they presented interesting variations.

Some of them, when they bloomed, seemed almost counterparts of the South American parent except that their petals recurved like those of the California lily. Some were spotted like the California parent, and some were quite without spots. As a rule, however, these hybrids, even though producing fairly abundant foliage, did not blossom at all, and at best they were small and insignificant, and within a year or two most of them had disappeared. They seemed to produce inferior bulbs that could not withstand the winter.

As further evidencing the lack of virility of these hybrids, it may be noted that all of them were

The Washington Lily

Mr. Burbank's experiments with the lily tribe have been almost numberless. He has made hybridizing and selecting experiments with almost every variety of lily under cultivation, and with many wild species. The specimen here shown is the species known as Lilium Washingtonia. Its strains have been blended with those of many other species in Mr. Burbank's gardens.

dwarfs. In striking contrast to hybrids of the *pardalinum* with other native lilies, none of them grew more than a foot in height and many of them not over six inches.

These dwarfs were rendered all the more striking by the fact that the miniature lilies reproduced in many respects the characteristics of their South American parent.

Another interesting hybridization was that effected between the *pardalinum* and a species of the native trillium, a plant familiar in our woods under the name of drooping night-shade.

The trillium is, of course, a lily, but, like *Alstroemeria,* it belongs to a different genus from the leopard lily, and its strikingly different appearance has already been referred to.

The hybrids produced by this strange union were dwarfs with broad, lily-like foliage, with blossoms that resembled those of the trillium—having three very broad, flat, greenish-white or yellow petals, and three narrower petals, like sepals.

A plant that thus bore a close resemblance as to foliage and general appearance to the leopard lily, yet which had blossoms like those of the wake-robin (though somewhat larger and coarser) made a very striking and interesting exhibit.

The species of trillium used in this cross was the common native *Trillium ovatum.*

The hybrids, although in themselves so interesting, proved lacking in vitality, and notwithstanding my efforts all died—not, however, before I had secured photographs of the strange trillium-lily combination.

Among all my experiments with the lilies, there is perhaps no other result quite as interesting as this hybridization with the trillium. Its results suggest the desirability of further experiments along similar lines.

There is an almost boundless opportunity for new series of investigations with members of this very extensive group. The plants may readily be cross-fertilized by the amateur, and interesting re-results must follow almost as a matter of course.

—The plant developer who pays heed to the fragrance of his flowers as well as to their other qualities, is almost certain to produce varieties that will be appreciated. The perfume of the flower and the flavor of foods are now-a-days receiving more attention than formerly.

The Purest White in Nature

Striking Color Changes in The Watsonia

BULBS are not usually measured by the cord. But I do not know how better to give an idea of my work with the Watsonia than to say that in recent years I have destroyed about eight cords of bulbs of this plant each season. A cord, it will be recalled, is 8 feet long, 4 feet wide, and 4 feet high.

If you will picture in your mind's eye eight cords of wood piled together, and recall that the Watsonia bulbs have corresponding bulk in the aggregate, and that each individual bulb is of the size of a small gladiolus, you will gain a fairly clear conception of one of the least satisfactory aspects of the plant experimenter's work.

These discarded bulbs, it should be understood, would produce very beautiful flowers. It seems a pity to destroy them, when so many people would be glad to have them for cultivation. But past experience teaches me that I have no alternative in the matter. If I permitted these bulbs to go out they would presently be exploited by someone as "Burbank's Best Watsonia," or under some still more spectacular title, and my reputation as a producer of fine varieties would suffer, as it has many times in the past through similar deceptions.

So there is no recourse, after selecting the comparatively small numbers of bulbs that give greatest promise for the carrying on of the experiment, but to destroy all of the remainder, even though, as in the case of the Watsonias, these may number a quarter of a million bulbs of considerable intrinsic merit, representing an enormous amount of labor.

A Flower That Rivals the Gladiolus

The Watsonia has been somewhat recently introduced, and has made its way slowly. So it may not be superfluous to tell the general reader that this plant bears a close resemblance to the gladiolus. It is indigenous to South Africa, one species being found also in Madagascar, and is represented by a number of wild species, among which two or three have pre-eminent importance from the standpoint of the horticulturist.

Perhaps the similarity of the Watsonia to the familiar gladiolus has interfered with its rapid introduction. Moreover the new plant is somewhat less hardy than the old one, and although it thrives abundantly in the climate of California it cannot as yet be grown satisfactorily in the gardens of the northeastern United States.

But there is one quality of the Watsonia, in its perfected varieties, that puts it quite beyond rivalry of the gladiolus. It produces a beautiful snow-white flower. As we have elsewhere noted, there has been, until recently, no truly white gladiolus. But the white of the Watsonia has been characterized as the "whitest white" in nature.

In point of quality of its whiteness, this flower is perhaps the only rival of the Shasta daisy. Each of these flowers is of a snowy whiteness, undimmed by the slightest trace of pigment.

The original wild forms of Watsonia, to be sure, are not white. On the contrary they are of various hues of red and pink. But there is apparently a spontaneous tendency to produce now and again a white variant, for at least two, and perhaps more, of these have been introduced from South Africa that were probably of independent origin. The white forms that are most familiar under cultivation are so similar that they have been thought to be identical, the origin of one of them being somewhat in doubt.

The white Watsonia whose origin is clearly known is descended from a plant discovered about

A Cluster of Watsonias

The Watsonia is a plant from South America that bears some resemblance to the gladiolus. Its flowers are comparatively small, but they are extremely graceful and pleasing.

eighty miles from the Cape of Good Hope by Mr. H. W. Arderne, of Cape Town. He took the plant to his garden and in 1892 had a goodly colony of the white flowers under cultivation. In due course they were introduced, and gained a measure of popularity among discriminating horticulturists, chiefly because of the exquisite whiteness of the flower.

Meantime, however, the original species has not been neglected, although comparatively little work has been done, in this country at any rate, in the cultivation of any of the Watsonias at the time my experiments commenced. Possibly the flowers would not have been prized but for the introduction of the white, as the others are rather dull and not particularly attractive in color.

Hybridizing The Watsonia

I have never been able to determine clearly whether the white variety named *W. Ardernei* in honor of its discoverer is identical with the variety introduced as *W. O'Brieni.* They are closely similar, but it seems not to be clearly established as to whether they come from the same stock, although the individuals from which the two races have developed were undoubtedly discovered independently.

On receiving the white Watsonia I planted it on a damp piece of sandy land at Sebastopol, but the bulbs did not thrive, and it was two or three years before any one of them bloomed. I learned through experience that the bulbs do not require too moist soil. They thrive in soil that contains a great mass of leaves, and under proper conditions they put out numerous branching stalks, about four feet in height, which for months together are covered with beautiful snow-white flowers, which have, as already stated, the size and much the general appearance of small gladioli.

The conditions of soil under which the Watsonia thrives are similar to those required by the gladiolus.

As soon as the colony of white Watsonias was fairly established, I began making crossing experiments, using for the cross the reddish pink species and including, a few years later, also a pink variety of the *W. Ardernei* that was sent out by a Dutch florist. As usual in these experiments, I hybridized with one species after another until in the course of a few seasons we had crossbred forms of multiple ancestry.

There were strains of the white Watsonia in them all, but also strains of the reddish and pink species.

By 1904 I had a crossbred colony of Watsonias numbering about fifty thousand seedlings. This doubled in the succeeding season, and in recent

Color Variation Among the Watsonias

Even in the wild state the Watsonias tend to vary in color, the usual hues, however, being red and pink. In developing the plant, Mr. Burbank has selected constantly with reference to the improvement of their color-schemes. Here are some samples of his selected varieties.

years the colony has attained the proportion suggested by what has already been said about the elimination of bulbs by the cord.

Needless to say there is great variety among these complex crossbred flowers. All of them retain the essential characteristics of bulb and stalk and manner of growth of the Watsonias. But in their size of flower, and in various important characteristics, they show departure from either of the parent forms.

Perhaps the most striking individual development is that of a pure white form of Watsonia that has double flowers. This double Watsonia is an unusual flower. The doubling has been brought about, not by the transformation of stamens, as in the case of a double rose or dahlia, but by growing a new circle of petals outside the old ones. This form of doubling, to be sure, is not altogether anomalous. It occasionally takes place in the case of the rose and the carnation, and I have known it to occur with the apple blossom. But it is not very common.

It is sometimes spoken of as supernumerary doubling, to distinguish it from the usual type in which each new petal takes the place of a stamen.

In addition to the double white Watsonia, the crossbred colony has presented single white ones that have much larger and more open blossoms than the original forms. Also some that grow on much taller stems, and others, on the other hand, that are dwarfed, and of more compact form. Not a few show marked improvement over the original form. If possible they surpass the original in snowy whiteness, and they not only bloom much earlier than the type form, but they are the most persistent bloomers, putting forth flowers almost perpetually throughout the season.

Strange Forms and Entrancing Colors

But even these snow white members of the colony are surpassed in beauty by some of their associates that show the most remarkable combinations and blendings of colors.

The parent forms, as we have seen, are reddish and white, but these blended hybrids present such combinations of colors as I have never seen in any other tribe of flowers except the orchids. It would be impossible to describe with any degree of accuracy the varied hues that these amazing and delightful blossoms present.

There are combinations of violet and rosy pink, soft apricot yellows, salmon, nearly pure yellow, yellow shading into pink, deep, dark crimson, light crimson, and purplish tints of many shades. And these various tones and colors are so shaded and blended as to produce an effect which, as I said, can be matched only among the far-famed orchids.

To produce races of flowers of such varied and entrancing hues from parent forms that had no exceptional distinction except for the whiteness of one variety, is to experience in full measure the best rewards that await the patient plant experimenter.

It chances also that these wonderful blossoms are not only individually delightful, but they are produced in such profusion as is not approached by the uncrossed races of Watsonias. And to cap the climax, these profusely borne and gorgeously colored blossoms are put forth throughout the season, early and late.

All in all, then, the new hybrid Watsonia must be given high rank among the aristocrats of the flower garden. They now lack nothing but an element of hardiness that will adapt them to grow in regions of the country where the climate is doubtful and the conditions are less favorable than those that prevail in California.

Somewhat earlier, the species *Watsonia coccinea* was introduced into the combination. It had smaller and more scattered flowers, long and tubular, and it was of doubtful value, and introduced with trepidation.

Some of the new hybrid forms presently developed long slender tubes, while the flowers sit close to the main stalk. Some have star-shaped flowers

Other Watsonias

Mr. Burbank has a very highly developed color sense, and he is particularly partial to flowers that have delicate hues. He has found the Watsonias peculiarly responsive, and has produced varieties showing delicate tints almost rivaling those of the orchids. Here is a random cluster from his enormous Watsonia colony.

with narrow pointed petals, others have wide rounded petals that give the flowers the appearance nearly of single dahlia blossoms. Still others are of a curious intermediate form—three of the petals being rounded, and three star-shaped.

Flowers of the last named type are quite anomalous. Petals of some of the old Watsonias were star-shaped, and others were rounded, but the combination of the two qualities is unique.

Among the hybrid seedlings there are some that are only seven or eight inches high, appearing with tufts of wide dark green leaves at a time when others with slender leaves have shot up to a height of eighteen inches or two feet.

We have seen similar differences among other hybrid plants. They show at once the diversity of the racial strains within their germ plasm, and the possibility of segregating and recombining traits of different ancestors.

There is a corresponding diversity as to the bulbs, and in particular as to the degrees of rapidity with which they multiply. There are varieties that will produce a bushel of bulbs from a single one in a comparatively short time, whereas others multiply very tardily. It is rather curious to note that the bulbs that are the most rapid multipliers are usually the ones that produce the best flowers and bloom most abundantly.

In dividing the bulbs of the hybrid seedlings, it is observed that some spread out naturally into bulbs of even size, and are easily pulled apart, like gladioli, thus being multiplied with facility. Others grow together in clusters that must be wrenched apart, breaking the bulb seriously, or else cut with a knife. All these matters are taken into consideration in the selection through which the few are singled out for preservation and the many are destroyed.

It is my custom, having selected a certain number for preservation, to cut away nine-tenths of the seed pods in order to strengthen the bulb, thus stimulating the fullest development.

The Care of Seedlings

As the Watsonia is not generally known, it may be worth while to give a few specific directions as to the raising of seedlings of this interesting plant.

In general it should be said that, where the climate is suitable, the Watsonia may be raised as easily from the seed as the gladiolus, and the treatment required is altogether similar. My method is to plant the seed in shallow, well drained boxes of sandy soil, as soon as they are ripe in the fall. By March we have, in each box eighteen inches square, perhaps a thousand Watsonias about six inches in height. They thrive very well when planted as thickly as this in the boxes.

Watsonias in the Proving Grounds

Mr. Burbank raises Watsonias by hundreds of thousands at Sebastopol. The picture gives an idea of the exceedingly pleasing effect of a row of Watsonias in blossoming time.

In the spring the choicest appearing plants are transplanted singly into rows. The ones that are not quite so choice are set out in the mass, by breaking up the soil into squares holding fifty to one hundred plants, all being planted in the open field, and by fall are ready to transplant into rows for testing.

A still more rapid method is to sprout the seed in moist sand at the proper season in the fall, just as the rains commence, sowing them quite thickly in drills eight inches apart and an inch deep in sandy soil, half the covering being sawdust. Scatter a few weeds over the surface to keep the winter winds and heavy rains from removing the sawdust. Early in the spring the young Watsonia seedlings come up as lustily as blue grass on a lawn.

Those that do not make a strong growth are allowed to stand thickly in the row another year, when they can be removed and planted.

For field culture, they should be planted four inches apart in rows four feet apart, being set quite deeply that they may resist the summer droughts.

Of course the more careful method first suggested is desirable if we are to raise plants of the finest quality. You also get results a year or two earlier by handling the plants individually. At the same time you insure the production of a plant from each seed, while when the plants are handled in a mass a good many of them no doubt fall by the wayside.

When treated according to the first method, many of the plants mature in the second year, and all of them in the third, so that they can be fully tested in that period. Moreover by the third year each bulb has developed quite a nest of bulbs about it, from each of which a new plant may be grown.

The results already attained with the Watsonia mark this plant as one that must take high place among favorites of the flower garden. What chiefly remains to be done is to make the bulbs more hardy, so that they are adapted to different conditions of soil and climate. At present the flowers are chiefly grown in California and shipped to the eastern market. But in due course races will be developed that can be grown in the east, and the Watsonia will come to rival the gladiolus and in some respects to outrival it for all the uses to which that flower is adapted.

Moreover it will perhaps prove possible, through hybridizing the Watsonia with the gladiolus, to develop new races of plants combining the qualities of each in a way that cannot be definitely predicted. Up to this date, 1914, I have

A Spray of Watsonias

It will be seen that the Watsonia flower is not altogether dissimilar to the flower of the gladiolus. The resemblance, however, is not so striking as that between the foliage of the two plants. The Watsonia flower is smaller than the improved gladiolus; it has, however, a charm distinctly its own.

produced a great number, say four of five hundred, hybrids between Gladiolus gandavensis and the Watsonia, in most cases using the pollen of gladiolus (chiefly because it is more abundant and the Watsonia is more certain of seed), but sometimes making the reciprocal cross. Only three or four of these blossomed, largely, perhaps, because a great number of them were very tender and were destroyed by the frost, although older plants of the Watsonia withstood the season.

It should be explained that the gladiolus does not withstand the coldest part of our winter any better than the Watsonia; but fortunately the gladiolus does not generally make a winter growth, so it may be left in the ground with less danger.

Whether most of these hybrids were made tender by crossing with the gladiolus, or whether some new element came in through the crossing, this experiment, which promised so much, was finally a failure. The seedlings showed the thick stem of the gladiolus. Some of them grew only a few inches, while others grew to great height.

Of the hybrids that blossomed, all died next year from gladiolus diseases.

It may be of interest to add that double white seedlings from the Watsonia have been produced; also double flowers of other colors, pink, light and dark salmon, and white.

ON THE WATSONIA

We have naturally had occasion, in recent chapters, to pay more attention to the matter of color than to any other single flower quality. For it might almost be said that flowers have been developed for color alone. A certain amount of attention has been given to modifying their forms but this has always been subordinated to the question of modifying their colors.

If attempts have been made to increase the size of the flower, and to multiply its petals, the central thought has been to produce a more striking color display. In exceptional cases, notably that of the orchid, anomalies of form add greatly to the interest with which a flower is regarded; but even with the orchids, it is unquestionably the delicate beauty of the coloration, and not merely the grotesqueness of form, that gives the flower popularity.

From the standpoint of the plant experimenter, the question of color in the flower is one that has perennial interest. In a very large number of cases new varieties are developed solely along the lines of color variation.

We have seen that there are almost endless modifications of color in the same flower, particularly in such variable races as roses and poppies and dahlias, and the case of the Watsonia, which has just come to our attention, illustrates the

Another Cluster of Watsonias

It will be seen that the Watsonias do not vary greatly as to form and shape of flower. Neither has there been any great modification as to the size of the individual blossoms, or their manner of distribution on the stem. There are individual variations, however, and the specimen here shown has rather exceptional quality.

interest associated with the modification of color even when no other change is involved.

The white Watsonia that was discovered among its pink fellows was given a new botanical name, and went forth to conquer the world captioned as a new sub-species. Yet it differed in no obvious regard from myriads of its fellows except in the matter of color.

It was pure white, and all of its fellows were reddish pink. That fact gave the one Watsonia distinction among the millions and insured the propagation of its progeny and their migration to the utmost corners of the earth.

Evolution of Colored Flowers

Something has been said in various preceding chapters as to the philosophy of color variation. The origin of the colored floral envelope has been ascribed to the influence of insects. We have been made aware that the floral envelope was developed as an advertising device to attract insects, that their services may be engaged for the transfer of pollen that is so essential in keeping up the necessary adaptability and vitality of a race of plants.

We have been led to infer that the floral envelope is one of the most recent developments in plant evolution, inasmuch as the earlier forms of plant life had no such apparatus and their successors developed it only after the evolution of the insect tribe. And we have doubtless been correct in ascribing the ready variability of the floral envelope to the fact of its relative newness. The stalk and branches and leaves of the plant have persisted, more or less modified in form but essentially unchanged in functions, from the remotest periods, and hence have attained a fixed and determinate arrangement of their hereditary factors that is difficult to disturb.

The conspicuous advertising sign that we call a flower has been put forth so recently that it has not attained any such degree of stability.

And in particular, the color of the flower is an endowment that, as contrasted with the general structure of the plant, must be thought of as only a thing of yesterday. We are justified in believing that even among the old tribes of plants—those whose primeval forebears have left their remains in the geological strata—the flower is the one structure that has been most subject to variation. And we may doubt whether there is any flower whatever that has not changed its color more or less within comparatively recent times, geologically speaking.

Something has been said as to the probable relations of the different primary colors in their various associations in the floral envelope. We have seen that flowers of the same species may vary from deep red to delicate violet, and that it is the commonest thing for a species that is usually gaudily colored to have representatives that are pure white. And it is possible, by a careful survey of the field, to draw conclusions as to the probable sequence of development through which the variously colored flowers have been evolved.

In the first place, certain inferences may be drawn from what is known as to the hereditary responses of different flowers, in particular when hybridizing experiments are performed, that at least give clues to the story of the evolution of color.

Analogies drawn from the study of the spectrum are also of aid, in connection with these practical observations, in developing theories of the philosophy of flower-coloration, which, if they cannot be said to be definitive, have at least a large element of plausibility and are full of interest.

The Physical Basis of Color

It has been suggested that the earlier forms of vegetation were probably red in color, where now the leaf structures in general are universally green; the basis for this belief being the observed manner of reaction between plants of green foliage and those of red foliage when hybridized, the fact that sea weeds are usually red, and the further fact that young vegetation, such as the buds of trees in the spring, is very generally red in color, the subsequent greenness being due to the development of chlorophyll granules.

Just why the chlorophyll granule is green is of course only matter for conjecture. But it is obvious that this is the ideal color for this purpose, otherwise it would not have been so universally adopted.

The presumption is that the plant finds it desirable to utilize the short rays of the upper part of the spectrum and the long rays of the lower part— those that stimulate chemical action chiefly, and those that are the greatest conveyors of heat, respectively — and that the intermediate rays producing the color green are not needed, hence are reflected or transmitted without influencing the plant.

A possible clew to the reason for this is found in the supposition that the plant needs the short light waves to enable it to carry out its chemical function of transforming water and carbon into sugar, and that this process is facilitated by having the tissues warmed by the long waves of the lower end of the spectrum.

It has been calculated that the sun beating on a leaf would raise its temperature to a point that would destroy the protoplasm and kill the leaf outright in a very short time were it not for the transpiration of water from the pores of the leaf, through which the temperature is equalized.

In spite of this danger the sunlight is known to be absolutely essential to the carrying on of life processes, but it is obviously desirable to limit the amount of heat as much as possible.

So the question of the heating effect of the sun must have a share in determining the color of the floral envelope.

A flower that blooms in the open and is exposed to the blazing rays of the sun may advantageously develop a glossy surface, just as a leaf does, in order to reflect the largest possible amount of light; and may in addition take on to advantage such transformation of its tissues as will make them reflect the long heat-bearing waves of the spectrum.

Such a flower, interpreted in ordinary language, is red in color—for of course that is the untechnical way of stating the facts that a given object reflects the long rays of light, and absorbs the others.

Contrariwise, it would be almost fatal for a blossom of ordinary texture to develop such consistency as to absorb the main bulk of the light-waves, inasmuch as such a blossom would soon be heated to a dangerous temperature. That, doubt-

A Typical Spike of Improved Watsonias

Mr. Burbank's improved Watsonias tend to bear the blossoms somewhat more compactly than was the custom with their progenitors. This picture shows a fairly typical cluster. Hitherto selection has been directed largely toward the improvement of the colors. It is probable that more marked improvement in other directions will be shown in the future.

less, is why flowers that are even approximately black are the rarest of all blossoms.

On the other hand, a flower that reflects all the rays of light, and hence that appears white in color, is given protection against the heating influence of the sun even though it grows in the open. When we add that white is a conspicuous color, the extreme abundance of white flowers is sufficiently accounted for.

It is true that flowers that bloom in the shadow, and particularly those that open in the twilight or at night, are almost universally white, also, but this is sufficiently explained by natural selection, since white flowers are more conspicuous at night than those of any other color. Moreover, it must be recalled that white objects transmit heat less readily than dark ones, so white is not a bad color for a night blooming flower, inasmuch as it conserves the internal heat even if it is not called upon to shut out heat from the sun's rays.

The Sequence of Color Development

All this is more or less axiomatic, but the further development of the theory of flower coloration involves a certain amount of assumption, and must be held only as a tentative theory.

Briefly stated, the essentials of the theory are that the original or earliest color of the flower was green in imitation of the leaf. All the older or primeval types of plants—palms, pines, cypress, ferns, etc.—have green flowers even to this day; in some cases slightly tinged with yellow. It is suggested that the color next developed was blue, the genesis of which involved but a slight modification of the molecular structure of the flower, inasmuch as the light waves that produce blue lie next to the green on one side in the spectrum.

The subsequent modifications of color were made in two directions progressively.

Some flowers were modified in the direction of the violet end of the spectrum, and others in the direction of the red end of the spectrum. The former were first light blue, then deep blue and indigo—represented among existing plants, let us say, by the larkspur and gentian—and ultimately violet. Flowers modified in the other direction were at first yellow then orange and finally red.

Evidence is lacking to answer the question as to which end of the spectrum was reached first—that is to say whether the flowers of violet color or red were first evolved. But possibly the two may have been developed somewhat contemporaneously, and they would thus take their place in the hereditary scale more or less on an equality.

In any event, we may be fairly assured that there were blue flowers and yellow ones, and probably also indigo colored flowers and orange ones in existence before there were flowers of pure violet or of deep red.

In other words we may feel that the violet-colored flower and the red flower are the newest things in the way of color in the plant world.

The time of development of white flowers is more debatable. There is reason to suppose that the white flower owes its whiteness to a combination of the conditions which by themselves would be interpreted as greenish-yellow and as blue respectively. It is known that these are the only pigments that can be compounded to produce the color white. So it is perhaps the safest assumption that white flowers were evolved by the hybridizing of greenish yellow ones and blue ones, and that their origin antedates the development of red flowers or of violet ones. In other cases whiteness is due to air in the cells, and may have been a very recent development.

Nor is all this a matter of mere unsupported assumption. The inference that such was the sequence of evolution of the different colors seems logical, inasmuch as it pre-supposes the modification of molecular structure of the flower substance in such a way as to reflect successive rays of light in a graded series—or rather in two graded series, one involving shorter and shorter rays as in the flowers that develop from blue to violet; the other

The First White Watsonia

The original white Watsonia was found as a "sport" in the midst of beds of Watsonias of ordinary color, in South Africa. The specimen became the progenitor of an entire race of white Watsonias, so individual as to be considered by botanists as a distinct variety. Mr. Burbank has of course used the white Watsonias along with the others in his crossbreeding experiments.

involving longer and longer rays in the series that developed from yellow through orange to red.

But an assumption based solely on this plausible analogy would not call for very serious consideration. The real strength of the theory lies in the support given it by the observed relations of the different flower colors when brought together through cross-pollenation of the flowers themselves.

It is believed, on independent grounds, that the relations of dominance and recessiveness in Mendelian heredity are determined exclusively, or at least in large part, by the newness or oldness, in an evolutionary sense, of the respective elements that make up a pair of Mendelian factors—referring, it should be understood, to the number of repetitions, not to the mere lapse of time.

If this assumption is correct—and there is a large amount of evidence drawn from many fields to support it—then a guide is at hand with which to test the theory of color evolution

Indeed, it is largely through the application of this guide that the theory of color evolution itself has been developed.

Making a practical application, it would appear that the color green, as manifested in a flower, is so remote an inheritance that it would be recessive to any and every other color; that blue would stand next in line of recessiveness; and that violet and red would be more or less on a par as colors of pre-eminent dominance.

White, according to theory, should be dominant to green and blue, but should itself be recessive or hypostatic when brought in combination with red or with violet. As a corroborative illustration, note that Mr. Burbank's blue poppies, crossed with white poppies, produce only white progeny.

It would also appear, that the factors for yellow and for blue, which are really balanced or masked to produce the color white, might be segregated when a white flower is combined with another white flower or with a flower of a different color, white perhaps disappearing altogether and being represented only by its disunited elements.

Moreover, we have already seen that where various colors are segregated, two dominant colors such as red and yellow being brought together in the same unit system, the two may neutralize each other and fail of tangible representation; just as the colors gray and black are known to do in the color scheme of the coat of the mouse.

The practical working out of the scheme is revealed in numerous cases that we have already examined.

Thus union of our yellow poppy with a white one that produced a crimson progeny finds ready explanation when we reflect that yellow is commonly formed by the blending of the pigments red and green, and that white is probably due to the blending of yellow and blue. The combination of the yellow flower and the white one may thus be supposed to have re-segregated the colors in such a way that yellow and blue were grouped to form white which was in turn submerged as a recessive factor when coupled with red; the result being that the progeny were all outwardly red.

In a similar way may be explained the result of combining the orange daisy with the white daisy; and in general the multiplex presentation of reds and pinks and yellows and whites in the hybrids of poppies and roses and gladioli and dahlias.

The fact that blue so seldom appears is explained by the assumption that it was the first color to be developed, after green itself, and hence that it is recessive to all the other colors. When a blue is brought out as in the case of my blue poppy, it is unearthed, as it were, with difficulty, and represents the bringing forth of a quality that has been submerged from time immemorial.

Of course there are numerous flowers—although as we have seen they are relatively rare—that are blue in color. These are races that have

The Improved White Watsonia

The original white Watsonias lacked something of purity of color. But Mr. Burbank has improved the variety by careful selection, until the white Watsonias in his present colony are of such a quality that their white has been described as "the whitest white in nature." In this regard, the Burbank improved Watsonias rival the Shasta daisy.

either retained the ancestral color unmodified because it served them well in adaptation to their environment; or they are plants in which the recessive blue, which must occasionally appear in the course of hybridizations, was preserved and restored to prominence because it served its purpose better than the other colors, whatever they might be, that had supplanted it. As might be expected, deep or indigo blue flowers are more abundant than light or pure blue ones.

It is perhaps not without significance that blue flowers have usually a white counterpart—the bluebell furnishes a familiar example. Blue and white, according to the theory just presented, lie close together in the evolutionary scale. Either will be recessive to red or orange or violet; and it is only flowers from the germ plasm of which these dominant colors have been largely removed that are likely to develop blue or white races.

Yet the fact that the white flower carries a strain of yellow is an ever present menace to its whiteness, as it may furnish the basis at any time for variation that will introduce yellow strains which stand a good chance of supplanting the blue and white ones.

Some further illustrations of the application of this theory of the evolution of color in flowers will appear in our subsequent studies. For the rest, the reader who is interested in speculations of this character will be able to make application for himself, and to test the theory as to its details, in particular if he enters the fascinating field of plant development.

[End of Volume IX]

—Flowers offer the most inviting field for the amateur, even while they still hold their full attraction for the practiced experimenter, and one can hardly proceed far with flower experiments without becoming interested in the phenomena of color-variation.

List of Direct Color Photograph Prints in Volume IX

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